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THE IDENTIFICATION OF NYMPHS OF THE GENUS *MELANOPLUS* OF MANITOBA AND ADJACENT AREAS[1]

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LITERATURE

One of the earliest attempts in North America to study and compare nymphal grasshoppers was made by C. V. Riley (45). The species he described are *Melanoplus atlanis (mexicanus)*, *M. spretus*, and *M. femur-rubrum*. Sixteen years later Howard (30) described for the first time the nymphs of *Schistocerca americana* Drury. The ground colours apparently were found to be quite variable, the dark markings fairly constant. Dampf (13), remarking on Howard's descriptions, maintained that his specimens were in the transitional stage between the solitary and migratory phases and that a description of these phases would have been quite different. Twenty-two years again after Howard's work there appeared good descriptions of immature *M. mexicanus* accompanied by excellent photographs. These were presented by Herrick and Hadley (28). Another attempt at comparative descriptions of nymphs was made by Morse in 1921 (38). In his key he separated *M. atlanis (mexicanus)*, *M. femur-rubrum*, and *M. bivittatus*, and several species of other orthopteran families and subfamilies. The characters used are insufficient for distinguishing each species from the remainder of their groups, but can be used quite successfully in Manitoba to-day for differentiating the species with which he dealt. Carothers (3), although she did not point out characters for identifying particular species, made some general observations worthy of note. It was her experience that familiarity with the adult characters made it possible to place a nymph in the correct genus and often even species. She found that colour and colour pattern could be used with some degree of assurance in Tryxalines and Acridines but that it was unsafe as a guide in identifying the later instars of Oedipodines.

Shortly before the appearance of Carother's paper Norman Criddle had begun the study which, had he lived, would likely by this time have covered all Manitoban species of Acrididae. On file at the Brandon laboratory are careful colour descriptions of over half the nymphal Orthoptera

[1] A study of the nymphal grasshoppers of Manitoba was begun nineteen years ago by the late Norman Criddle but his untimely death in 1933 left the project unfinished. In 1935, shortly after the intensified study of grasshopper ecology in the province had again emphasized the need for a method of identifying immature hoppers, the problem was taken up by the writer, and the information presented herein represents the first step in an attempt to fill that need.

A portion of the work was done during a period of nearly two years at the University of Minnesota. The remainder was carried on in Manitoba, partly at the Dominion Entomological Laboratory, Brandon, and partly at the associated field station at Treesbank.

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of the province, and in many instances excellent drawings accompany the descriptions. In spite of his untimely death he had succeeded in publishing the most comprehensive papers on immature Orthoptera yet to appear in North America. In his first paper (7) he confirmed the generalizations made by Carothers and described the nymphs of 9 species, 6 of them of the genus *Melanoplus*, but without attempting any great degree of comparison. In his next paper (8) he characterized the Tryxalinae, Oedipodinae, and Acridinae (Cyrtacanthacrinae) and described (with emphasis on the first instar) a number of species in each group, adding 4 more to his previous list of 6 species of *Melanoplus*. Four excellent plates of first instar nymphs are included in the paper. He referred to the reasonable constancy of the colour pattern, especially that of the hind femur, and pointed out the usefulness of the male genitalia in the later instars. Although comparisons are more frequent than in the previous paper there is still a notable lack of them. In a later paper (10) he redescribed the more injurious species of the genus, figured the first and a few fourth instar nymphs, and gave a brief key to the first stage hoppers. Two other papers (9, 11) describe an additional species each.

One of the most intensive pieces of work yet conducted on the morphology of the nymphs of any species was submitted in 1926 to McGill University by R. M. White (61). This unpublished thesis contains a complete and excellent series of detailed drawings of all stages of both sexes of *Camnula pellucida* Scudder. Although the species is not compared with any other, two conclusive statements are of interest to the present study: (1) "*Camnula pellucida* Scudd. varies greatly in different specimens of the same stage of growth"; (2) "In general the nymphal stages are very much like the adult except that the sclerites are not as clearly defined." The colours of the same species had been previously described and the first stage figured by Treherne and Buckell (56).

The occasional occurrence of a sixth nymphal instar in *M. mexicanus* has been mentioned by Parker (41), and Shotwell (47) figured and described this "extra" instar in a paper clearly defining the various stages and the two sexes.

For Europe, Asia, Africa, and South America there is a considerable number of papers, among them Coleman (6), Lebedev (33), Dampf (13), Zolotarevsky (62), Faure (19), and especially Uvarov (57), in which descriptions are given of immature stages of individual species, especially of those exhibiting phases. Little or no attempt at comparison with other species is evident in any of the papers. About the time that Criddle's more extensive papers were published on this continent there appeared a number of publications of a similar nature by Russian workers, Dovnar-Zapolsky (14, 15) and Bey-bienko (1), which the writer was not successful in securing until after the work had been completed.

In his first paper (14) Dovnar-Zapolsky included a key to 9 species, each in a different genus, and to 4 species in the genus *Dociostaurus*. In the second paper (15) his keys, one to earlier and one to later instars, separate 22 genera, but there are no keys to species. He does, however, give fully descriptive keys to separate the different instars of a single species in each of 12 of the genera. In the paper by Bey-bienko there is a key to 24 genera, mostly the same as those listed by Dovnar-Zapolsky (15).

Following this are 12 keys separating 2 species in each of 12 genera, and 3 keys separating 3 species in each of 3 genera. Considerable space is devoted also to biological and ecological observations.

The two authors use practically the same set of characters. Beybienko states that, in general, morphological characters are best for separating genera, and colour characters for species, but sometimes the opposite is true. In some groups of species colour is quite useful; in others colour is variable but colour pattern can be relied upon. In still other groups colour pattern, regardless of age or sex, is too variable but ecological factors can be used. In a few instances distribution records are the sole means of differentiating species.

The characters used for separating nymphs of the various genera are those commonly applied to the adults. Thus the slope of the frontal carina and its shape, the ratio of length to width of head, the presence or absence of foviolae and their shape and position, the shape and size of the vertex, shape of antennae, the degree to which the pronotum does or does not extend over the abdomen, the general shape of the pronotum and its carinae and sutures, presence or absence of prosternal tubercle and its shape, and the presence or absence of an arolium, are characters stressed by both writers.

In separating species within a genus, structure is used occasionally but the use of colour and colour pattern is more common. Dovnar-Zapolsky's key to species of *Dociostaurus*, the only one containing as many as 4 species, is fairly representative. Below is a general translation.

1. Occipital ridge present.....*D. albicornus*
   Occipital ridge absent.....(2)
2. Light stripes of X-pattern of pronotum are of uniform width but are slightly broken in middle.....(3)
   Light stripes of X-pattern of pronotum are distinctly broken in middle and each portion extends into light, often white, triangles.....*D. kraussi*
3. Genal stripe almost always present.....*D. brevicollis*
   Genal stripe almost always absent.....*D. maroccanus*

MATERIALS AND METHODS

Sources of Material

A study has been made of representatives of the following 21 species:

Melanoplus angustipennis (Dodge)
Melanoplus bivittatus (Say)
Melanoplus borealis junius (Dodge)
Melanoplus bowditchi canus Hebard
Melanoplus bruneri Scudder
Melanoplus confusus Scudder
Melanoplus dawsoni (Scudder)
Melanoplus differentialis (Thomas)
Melanoplus fasciatus (F. Walker)
Melanoplus femur-rubrum femur-rubrum (DeGeer)
Melanoplus flavidus flavidus Scudder
Melanoplus foedus foedus Scudder
Melanoplus gladstoni (Scudder)
Melanoplus huroni Blatchley
Melanoplus infantilis Scudder

Melanoplus islandicus Blatchley
Melanoplus keeleri luridus (Dodge)
Melanoplus mexicanus mexicanus (Saussure)
Melanoplus occidentalis occidentalis (Thomas)
Melanoplus packardii Scudder
Melanoplus stonei Rehn

All of these occur in the province of Manitoba except *bowditchi canus*, *differentialis* and *occidentalis occidentalis*. *M. differentialis* was obtained from Minnesota and Nebraska and the other two species from Alberta. Except for *borealis borealis*, which Hebard (25) has recorded from Aweme, Manitoba, and which Donald Denning (unpublished) collected in 1937 at Churchill, Manitoba, all species and subspecies occurring in the province are believed to be represented. The Manitoba material was obtained largely from Aweme but large numbers of *mexicanus* and *infantilis* were secured from Lyleton, *bivittatus* from Arnaud, and *femur-rubrum* from Miami. The *stonei* and *bruneri* were all obtained from the Sandilands Forest Reserve east of the Red River. All specimens of *packardii* were from Lyleton. In a few instances the series studied was limited in part or entirely to a small number of specimens preserved 7 to 9 years ago by Norman Criddle. This was true of all instars of *islandicus* and *huroni*, of all except the first instar of *borealis junius*, of the second and fifth instars of *bruneri* and the fifth instar of *infantilis*.

At first no material was used except that obtained from known adults. These were collected in the field and placed in breeding cages until the end of the oviposition period when they were shipped to Mr. Morgan Hebard who very kindly made the final determinations. As the writer became more familiar with the habitats and nymphal characteristics of a species, collections were made directly from the field. In instances where eggs of doubtful identity were secured in the field, a few males were reared to maturity from each pod and these also received the attention of Mr. Hebard.

Condition of Preserved Specimens and Methods of Preserving

Preserved specimens, even those stored as long as 9 years, were often in excellent condition. Others, however, were not entirely satisfactory even though obtained during the past year. It is not easy to preserve specimens at just the right stage. Nymphs that are killed too soon after moulting are apt to be poorly filled out and rather soft; if taken too late the integument of the next stage will have begun to form, a process apparently initiated but little later than half-way through the preceding stadium. A common disadvantage inherent in such specimens is the tendency of the tissues to withdraw slightly from the exoskeleton. This makes photographing rather difficult since the empty, transparent sheath formed by the old integument permits the passage of rays from the back light. Evidence of this will be seen in some of the plates.

Although properly preserved specimens will retain their colour pattern for years, an alteration of the general colouring commonly occurs. Some darken rather quickly, others more slowly, while in some instances an actual fading seems to take place. For this reason, specimens of some species, although satisfactory from the standpoint of markings, show in the plates

as darker or lighter than species which they resemble more closely in life. One notable example of this is Figure 11 in Plate VII. This species *M. occidentalis*, in life is very similar in general appearance to *M. gladstoni*. Reference to Plates III to V shows how dull many of the preserved specimens are when compared with the fresh ones.

Some of the material was preserved in Hood's solution[1], and a very little in one part commercial formalin and 19 parts water, but the bulk of it was stored in 70% alcohol. These solutions were about equally satisfactory but the green colour was not maintained by any of them. It was found that the colour pattern was best preserved by dropping the live hoppers directly into the preservative. When specimens were first killed in hot water much of the contrast between light and dark markings was lost, some species being more affected than others.

In dried nymphs all the markings remain reasonably distinct except those of the eyes. These are always altered to some extent and as a rule are completely destroyed. Moreover much shrivelling of the parts makes examination difficult.

Breeding and Rearing Methods

In breeding and rearing the partly described (7) methods of Norman Criddle were used. Two-quart glass preserve jars, with an inch of slightly moistened soil in the bottoms and wire screening pressed into the tops, served as cages. Whenever possible direct sunlight was used as the main source of heat, raising the temperature commonly to between 90 and 100° F. It was found possible to rear individuals in unlighted temperature cabinets without any apparent abnormality in either colour or structure, but mortality was greater. Mortality was also high during a period when rearing was being done in a greenhouse where a high humidity was maintained.

During the summer months the preferred foods (see Criddle, 12) were used as much as possible for both breeding and rearing. The foods of the more restricted feeders, however, could not be grown conveniently during the winter and other diets were found reasonably satisfactory. Wheat seems to serve quite well as a basic food but it was found desirable to supplement it with dandelion, lettuce, and wandering jew. In some instances too continuous a diet of the last mentioned plant seemed to increase the mortality.

Methods of Study

To make a complete study of all the minute sclerites of all 5 instars of both sexes of all 21 species would obviously require many years of patient and industrious research. Realizing this it was decided to select 2 species on which such a thorough comparative study could be made, the results to be used as a guide in less intensive examinations of the remaining forms. *M. femur-rubrum* and *M. bivittatus* were selected for this purpose. One reason for the selection was that *femur-rubrum* is the type species of the genus. Another reason lay in the fact that the lighter coloured forms of *femur-rubrum* are very easily confused with the darker forms of *bivittatus*

[1] This solution is made up as follows: 18 oz. 95% commercial ethyl alcohol; 6 oz. distilled water; 2 oz. 7% glycerine; 2 oz. acetic acid; 1 oz. benzol.

and a method of separation based on structure would be a decided advantage. The main reason, however, was that the adults are, for the genus, very different structurally, and if morphological differences were to be found in the nymphs of the genus it was decided that they would surely be discovered in a comparison of these 2 species.

For examination of structural details it was found advantageous to clear the hoppers in potassium hydroxide before dissection and then mount the parts on slides in Canada balsam. Staining, although a definite visual aid in handling the minute sclerites, was found to be of little value otherwise.

Methods of Photographing

The manipulation of specimens for photographing presented a distinct problem in itself. After many unsuccessful attempts to cement pin points in an upright position on various types of glass a satisfactory mount was finally secured, on the suggestion of Dr. R. D. Bird, by forcing the pins through a thick sheet of celluloid. The length of the points and their spacing necessarily varied with the size of the specimen being photographed. One pin was used for impaling the thorax, the next spaced so as to attach the head, a third was set to hold the right leg above the position of the abdomen (as in plates III to VII) and a fourth and longer point to hold the left leg in a corresponding position below the abdomen. A section of a millimeter rule was then cemented to the celluloid on a level with the point of focus to show the exact magnification of each specimen. This saved considerable time and tended to prevent inaccuracy since the different subjects were photographed at different magnifications[1]. To prevent reflection from the integument the specimen was submerged in 70% alcohol in a petri dish. Subjects of different sizes, but for use in the same series, required slight differences in focusing. This was accomplished by placing the submerged specimen on an adjustable opal glass platform by means of which it could be raised or lowered without altering the focal length of the camera, thus leaving the magnification unchanged. All exposures were sufficiently magnified so that the figures presented in the plates could be secured by means of contact prints rather than enlargements.

RECOGNITION OF INSTARS

A study of morphological characters is complicated by changes that occur as the insect develops, hence to use such characters intelligently recognition of the various instars is essential. Dyar (16), working with lepidopterous larvae, used head width for this purpose and his principle was applied to various orders by different workers, Przibram and Megusar (43) finding it satisfactory for determining the stages of the orthopteran, *Sphodromantis bioculata* Burm. Hodge (29) found that the instars of *M. differentialis* were in general indicated by the length of the hind femora but that considerable variation occurred. No doubt the sizes of still other skeletally limited body parts could be used to determine nymphal instars but even if such determinations could be made with perfect accuracy the method would be a very cumbersome one, a separate table being required for nearly every species.

[1] To conserve space only one print of the rule was included with each set of plates of the one series.

Spett (53) was able to determine the 4 instars of *Chorthippus parallelus* Zett. quite satisfactorily by means of the external sex organs, but Else (18) working with *M. differentialis*, found these characters not entirely dependable.

An excellent key to the stages of *M. mexicanus* is given by Shotwell (47). He used wing pads as the major character, with length of third femur and number of antennal segments as next in importance. The general shape of the pronotum, condition of the median carina, shape of the supra-anal plate, appearance of the cerci and podical plates, are all used more or less incidentally. The writer has found this key quite satisfactory except as indicated below for the number of antennal segments.

A method more or less applicable to all species is that used by Riley (45), Carothers (3), Morse (38), Criddle (8) and others. These workers determined the various instars on the basis of the development of the antennae, pronotum and wing pads. The writer has found, as did Else (18), that in the genus *Melanoplus* the antennae and wing pads used together are more dependable than any other structures.

The five instars most commonly present have 13, 17, 20, 22, and 24 antennal segments, respectively. Failure of some of the segments to divide completely not infrequently causes variations to occur in these numbers. It is easy, also, to overlook certain divisions that are actually present but are inconspicuous. Thus, in the early instars especially, the two terminal segments, the last of which is both narrow and short, are frequently counted as one. Counting these as 2 no matter how poorly the division is indicated, and counting the scape and pedicel, the occurrence of less than 13 segments in the first instar was rare in the material studied; 17 segments was the usual number for the second stage with occasionally just 16; 18 to 20 segments occurred in the third; 21 to 22 in the fourth; and 23 to 24 in the fifth instars.

The development of the wing pads in the 5 normal instars is shown for *M. femur-rubrum* in Plate I. In the first instar the pads are scarcely evident, being indicated merely by an almost indiscernible fold. In the next two stages the pads grow downward and backward but often not enough more in the third instar to make it easily distinguishable from the second. Venation, however, is commonly indicated in the former but not the latter. In the fourth instar the wings are turned upward, the tegmina lying underneath those on the metathorax. The latter almost touch each other but only at their tips. In the fifth instar they are more or less horizontal and approximate each other for half of their length.

Thus the first 3 normal instars can be separated from the last 2 by the position and development of the wings and from each other by the number of antennal segments; the last 2 can be determined most safely on the basis of wing development.

In all brachypterous species except one (*M. islandicus*) the wings though usually somewhat shorter than in corresponding stages of long-winged species have the same general form as these latter. *M. islandicus* (Plate I, Figure 6) has extremely abbreviated wings in the adult stage and correspondingly short ones in the immature stages.

Parker (41) and Shotwell (47) have described an "extra" instar as occurring in some individuals of *M. mexicanus* between the normal third

and fourth stages. This Shotwell characterizes as having 19 antennal segments, as being almost as large as the normal fourth instar, and as having wing pads that still point downward as in the third instar but are more elongate, are pointed, and show more distinct venation. It has also been reported by Criddle (12) for *M. bivittatus*, especially females. Although not encountered in the rearing work done during the present study, occasional specimens taken in the field except for the presence of 21 antennal segments definitely answer Shotwell's description. As to the possible cause of the "extra" instar in *M. mexicanus* Parker (41) reports—". . . . it was found that when reared at 22° and 27° C. there were always 6 instars, while at 32° and 37° C. there were only 5 . . . . At alternating temperatures of 32° C. for 8 hours daily and 12° C. for 16 hours daily there were 6 instars, while at 37° C. for 8 hours and at 12° C. for 16 hours there were only 5 instars." In *M. differentialis* the "extra" instar appears to be the rule rather than the exception and Hodge (29) has reported the occurrence of as many as 7 and 8 instars for a very few individuals of this species. Uvarov (57) mentions that in *Dociostaurus kraussi* the females go through one more instar than the males, and in the rearing done at the Brandon laboratory an "extra" instar has been encountered in females of *M. bowditchi canus* but not in males. The writer has not observed this phenomenon in other species but it is quite possible that it does occur. In this paper the "extra" instar is disregarded in the descriptions because of its close resemblance in both colour pattern and structure to the normal third instar. Thus when the terms fourth instar and fifth instar are used they refer to the last two stages even in *M. differentialis*.

Key to Normal Nymphal Instars

1. Wing pads, when evident, pointing downward and backward.....(2)
   Wing pads turned upward.....(4)
2. Antennae composed of not more than 13 segments; wing pads not apparent; posterior margin of pronotum transverse, often slightly notched medially.....*First instar*
   Antennae composed of more than 13 segments; wing pads evident; posterior margin of pronotum rounded, never notched.....(3)
3. Antennae composed of not more than 17 segments; wing pads extending but slightly downward and backward, no veins indicated.....*Second instar*
   Antennae composed of 18 to 20 segments; wing pads quite evident and showing slight venation.....*Third instar*
4. Wing pads short, those of opposite sides touching, or nearly touching, only at tip; antennae with 21 to 22 segments.....*Fourth instar*
   Wing pads more elongate, horizontal, those of opposite sides approximating each other on distal half; antennae with 23 to 24 segments.....*Fifth instar*

SEX DIFFERENTIATION

Since in this genus the species are differentiated largely on the basis of the genitalia, especially those of the mature male, it is required that one be capable of distinguishing the 2 sexes in all stages. Nelson (40) states that the sexes can be quite readily differentiated in the embryo. Shotwell (47) clearly describes and figures the different developmental stages of the external genitalia of the males and females of *M. mexicanus*. The same structures of *M. bivittatus* and *M. femur-rubrum* are shown in Plate II. The only constant difference in the first instar is the presence in the females of the rudimentary ventral or first valves of the ovipositor. These are evident as 2 minute tubercles on the posterior margin of the eighth sternite.

The upper or third valves are usually separated from the ninth sternite by light sulci and the ninth sternite itself is not as convex as the same sclerite in the male. The difference, however, is very slight and the sulci often indistinct or absent. Under these circumstances the sexes look very much alike, and if the ventral valves are overlooked the females are likely to be mistaken for males. In the second instar the ovipositor valves are all easily distinguished but no other differences are evident. In some species, at least, the cerci are slightly differentiated in the third instar and in a few species the furculae begin to make their appearance at that stage. The ovipositors of the female and subgenital plate of the male are, of course, even more distinct. In the fourth and fifth instars the same structures, as shown by the figures, become increasingly differentiated.

Secondary sex characters have not been studied but no doubt these are present in the species being considered. Spett (53) studied 8 such characters in *Chorthippus parallelus* Zett. These consisted of the head width, width of the pronotum, length of the pronotum, distance between the lateral carinae of the same, length of the right hind femur, length of the right antenna, length of the right tegmen, length of the right wing. Sexual differentiation in these characters appeared gradually with advancing age, being absent in the first instar, absent or nearly so in the second, evident in the third, quite distinct in the fourth (last nymphal) instar and greatest in the adult. Differences in the external sex organs, on the other hand, were clearly indicated in both sexes at the time of hatching, these differences naturally increasing with advancing age. The same author (54) compared *C. parallelus* with *C. albomarginatus* and found that the differences in secondary sex characters exhibited by the 2 species were more an example of sexual dimorphism than of species difference. On the other hand, the more constant species differences that occurred throughout the various instars developed independently of the secondary sex characters.

STRUCTURAL CHARACTERS

The study of structural characters, as pointed out in the preceding sections, is complicated by the existence not only of sexual differences but of developmental differences as well. This is manifested in the group by an increasing similarity in the species as one proceeds from the adults to the first instars, and since the species are delimited largely on the basis of the male genitalia the probable failure of diagnostic morphological characters in the early instars, especially females, could perhaps have been anticipated. The structures discussed are indicated in text Figure 1.

Of the various individual characters, body size and size of body parts, both absolute and relative, were considered impracticable and passed over with little or no study. In the first place, assuming that the individual variation is small enough to make accurate species determination possible, the method would be extremely cumbersome to use where so many instars of both sexes of so many species have to be taken into consideration. Moreover, the use of size is further complicated by the occurrence in some species of the "extra" instars that cannot be properly compared with normal instars of other species. Still further discouraging its use is the fact that in species most nearly alike, a comparison of individuals has shown that although there may be slight differences in mean size, there is considerable

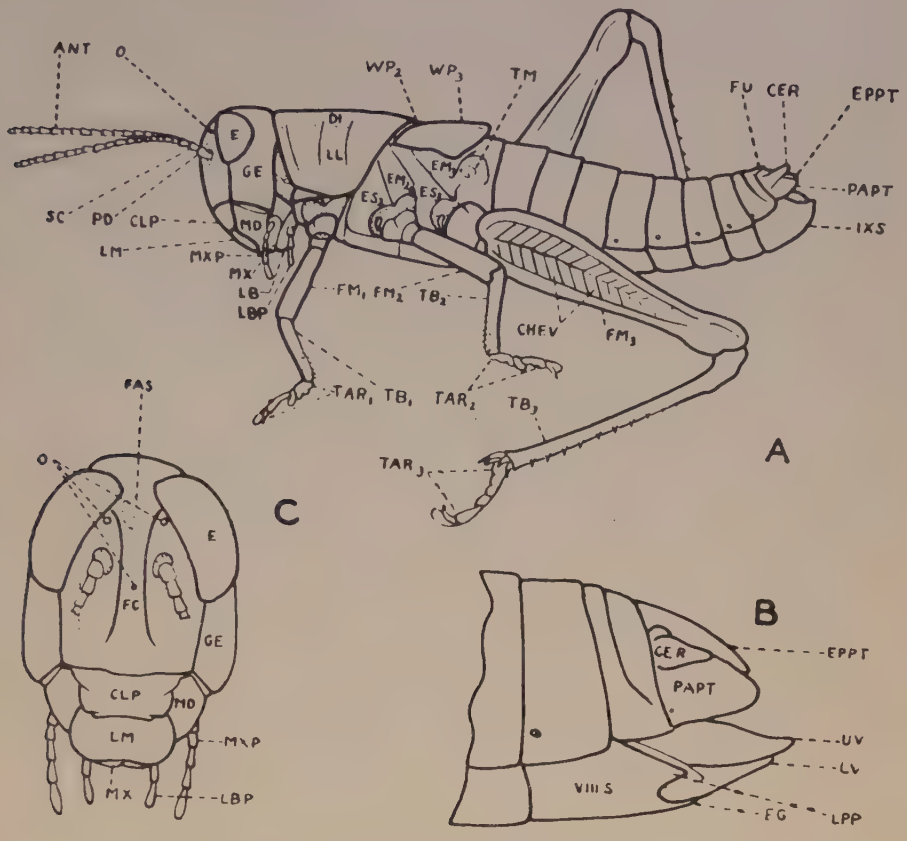

FIGURE 1. A. Lateral view of fourth instar male. B. Lateral view of genitalia of fifth instar female. C. Anterior view of head of third instar female.

ANT, antenna
CLP, clypeus
EG, egg guide
EM, epimeron
FC, frontal costa
GE, gena
LBP labial palpus
LM, labrum
MD, mandible
MXP, maxillary palpus
PAPT, paraproct
TAR, tarsus
UV, upper valvula
WP3, wing pad of metathorax overlying wing pad of mesothorax
CER, cercus
DI, disk of pronotum
ES, episternum
FM, femur
IXS, subgenital plate
LPP, latero-posterior projection
PD, pedicel
TB, tibia
VIII S, eighth sternite
—1, prothorax
—3, metathorax
CHEV, chevrons
E, compound eye
EPPT, epiproct
FAS, fastigium
FU, furcula
LB, labium
LL, lateral lobe
LV, lower valvula
MX, maxilla
O, ocelli
SC, scape
TM; tympanum
WP2, wing pad of mesothorax
—2, mesothorax

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overlapping in all stages; and in species where the difference in size is unquestionably significant, other more easily usable characters are sufficiently distinct and constant to make unnecessary the use of such a clumsy characteristic as size. Above all it is felt that anything as variable as body size or size of body parts should be studied over a very large series of individuals of all instars and both sexes, a task quite out of proportion to the obvious degree of usefulness of the results. Thus, for example, the hind femora of some species are undoubtedly longer than those of others, but it is necessary to know the instar before such a character can be used, yet femur length is itself sometimes used as a secondary criterion for stage of development. The same is true of antennal length. The ratio of eye width to the distance separating the eyes at the vertex is of value in separating the adult females of some species; it is, however, of little or no value in males or in early nymphal females.

The shape of the various sclerites, the mouth parts, compound eyes, ocelli, fixed sclerites of the head, hypopharynx, epipharynx, pronotum, mesonotum, metanotum, pleural and ventral thoracic sclerites, legs, wings, spiracles, tympanum, epiproct, paraprocts, furculae, cerci, subgenital plate, ovipositor valves, and eighth sternite, all received attention. It was found that none of these showed specific differences throughout all the instars. The light-coloured mark that occurs at the base of the antennae in adults, and is a valuable aid in separating females of some species, does not appear at all in the nymphs. The prosternal tubercle, though of slight value in the fifth instars of a few species is of no value in any of the other instars; in fact, it cannot be seen in the first two instars and sometimes not even in the third. The posterior margin of the pronotum, characteristically shaped in adults of at least 1 species, *islandicus*, is of little value in nymphs except perhaps in the fifth instar. The distance separating the metasternal lobes, although quite variable, is greater in *huroni* than in any of the other species. This difference is not as great in the nymphs but is apparent to some degree in the fourth and fifth instars. The number of spines on the anterior row of the second femora is commonly greater in some species than in others, but in every species studied a moderate number of individuals carried the same number of spines as the species from which it was desired to distinguish it. The wings were found to be specifically designed only in *islandicus* and even in that species were of no value except in the last two nymphal instars.

The abdominal structures, particularly the genitalia (see Plates IX to XII), showed a little greater promise and deserve more attention. The furculae are particularly useful in some instances. Since they do not occur at all in some species and appear as early as the third instar in others, their mere presence serves for differentiation, and in a few instances they show characteristic size and shape. The fifth instar males of a majority of species can be identified by means of the cerci, for by that time these structures have begun quite noticeably to have taken on the characteristics of their full development. In many of the species they are also helpful in the fourth instar but in very few do they show sufficient differentiation in third stage nymphs. The tip of the male subgenital plate also begins to take on the adult characteristics in the last 2 instars and in those stages is an aid in identifying a few species. The internal male genitalia, used so

advantageously in adult males (Hubbell, 31), are of comparatively little value in the nymphs. In both fresh and well preserved fifth instar nymphs the parts though poorly pigmented are sufficiently sclerotized to show a definite resemblance to the adult. In the fourth instar some individuals of a few species could be separated on that basis but not all of them, and unless material is quite well preserved the parts break down and the distinctive structure destroyed. Even in fresh nymphs it is difficult to expose the internal genitalia without spoiling the specimen.

There are females of several species that have distinct lateral projections on the posterior margin of the eighth sternite (see Plate XII, Figure 18B) while others have none. In most of these the projections are noticeable in the fourth instar, and in 2 species, *bivittatus* and *differentialis*, the degree of development is also characteristic. The shape of the upper valvulae, a valuable character in grouping adult females, can also be used for grouping the fifth instars, but is of doubtful value in the fourth.

It will be seen from the above discussion that *no structural characters have been discovered that can be used satisfactorily for identification of the first 2 instars, that only a few third instar males have structures that can be used as a guide to species, but that most fourth and fifth instar males and some fourth and fifth instar females can be traced to species from a knowledge of the adult structures.* Although this is a disappointingly incomplete state of affairs it is of greater value than would at first appear, for, as pointed out in a later section, a series of specimens taken from one locality usually contains a few specimens more advanced than the others which can thus be more readily identified and in turn can be used, by comparison, as an aid in identifying the earlier instars.

STRUCTURES REQUIRING FURTHER STUDY

There are a number of structures which have not yet received all the attention they may deserve. For instance, in comparing the two species in Plate II, it will be observed that the tips of the subgenital plate are a little more widely separated in *M. femur-rubrum* in proportion to the size of the sclerite, than they are in *M. bivittatus*. This difference appears to be constant and may possibly be of some value in other species in which they have not been studied. Length of antennae, although as already stated a cumbersome and difficult character to use, deserves further study especially in the early instars where identification is difficult. Another structure which should be studied in all species, for identification of mature females if not nymphs, is that which Snodgrass (51) figures for *M. femur-rubrum* and terms the second basivalvular sclerite, and which Walker (59) figures for *M. bivittatus* and refers to as the third basivalvula. In the few specimens in which this sclerite has been studied by the writer, it appears to be constant and fairly diagnostic. The epiproct although quite variable does appear in some instances to show specific differences, but it requires considerably more attention before its degree and manner of usefulness can be stated. The same is true of the chevrons marking the outer surface of the hind femora. The *campaniform sensilla* of the legs, which Pringle (42) has found to occur regularly and in a fairly definite pattern on *Periplaneta americana* L., might prove useful in some species of *Melanoplus* although their practical value would be greatly reduced in any case because

of their microscopic nature. Thus the writer does not claim to have exhausted the complete stock of possible structural diagnostic characters of all the species, but the ones discussed are certainly the most usable.

COLOUR AND COLOUR PATTERN

A consideration of all the factors known to cause variation in the colours and colour patterns of grasshoppers would lead one to conclude without hesitation that the characterization of species on that basis was entirely out of the question. In the first place it has been shown by several authors, Dampf (13), Uvarov (57), Zolotarevsky (62), Tarbinskii (55), and others for migratory locusts, by Rubzov (46) for non-swarming hoppers, and by Faure (20) for *M. mexicanus* of this country, that there are marked colour differences in solitary and migratory phases of the same species. Moreover, according to Rubzov, interwoven with the phase colorations are a number of variations dependent entirely upon the mechanisms of heredity, and King (32) has established the fact that melanism is inherited in *M. differentialis*. Inherited differences in colour pattern occur in the pigmy locusts also (Nabours, Larson, and Hartwig, 39). To further complicate matters it has been shown experimentally by Eisentraut (17), Parker (41), and Faure (19) that differences in environmental conditions can cause distinct differences in colour.

Certainly the majority of species discussed herein show considerable variation in basic colours, green forms being not uncommon even in some of the darkest of them. Which of the three factors, genetic constitution, phasic condition, or immediate environment, brings about these variations is something beyond the scope of this paper, but the fact remains that they do occur. And yet, in spite of these variations, basic colour has its place in that complex of impressions that leads one to recognize the species of nymphal grasshoppers, for, over a period of years in an area the size of a province or state, the great majority of individuals of a given species will be of a more or less characteristic colour.

Colour pattern, as distinct from basic colours, also has its limitations since there is a general tendency for the dark areas to contract or expand with the lighter or darker colour forms of the species. Certain parts of the body do, however, exhibit a definite type of pattern which, once its variability and limitations were firmly fixed in mind, has been found extremely useful in Manitoba. In some species, it is true, the pattern is not as sharply defined in the early instars as it is later, but in the majority of them it holds throughout all stages and in a few it is even more striking in the first instar than in the others. Where colour pattern fails, as it not infrequently does in a few species and more rarely in nearly all species, the early instars cannot be identified with certainty.

The general pattern (i.e., the ratio of dark to light shades, the degree of uniformity or "brokenness" of the dark areas, the degree of contrast as between light and dark shades) is subject to considerable variation but shows some degree of specificity. Considering more limited areas, distinct and reasonably constant differences of colour and pattern have been exhibited by most species in the compound eyes, the genae, the lateral lobes of the pronotum and the hind femora.

The markings on the hind femora are particularly useful and in most species they are remarkably constant, varying but little in individuals and showing the same characteristics in the early as well as the later instars. Dark forms of a few of the species, however, although recognizable with practice, would not be recognized from a description of typical specimens, and the markings on the femora would probably throw the specimen into an entirely different group.

The markings on the compound eyes (see Plates III, IV, V and VIII) are sufficiently specific and sufficiently constant in a few species to enable the identification of all nymphal stages of both sexes without the aid of any other character. Where not specific, there is often sufficient difference that groupings may be accomplished thereby, and in some instances species may be separated that have already been grouped by means of other characters. In several species the markings are subject to considerable variation in individuals, the tendency in general being for the first instar to be less constant than the remaining stages. This character, like others, is dealt with fully in the descriptions of species.

The lateral lobes of the pronotum have markings which, although quite variable, become extremely useful with practice. Except in the very greenest forms of *foedus*, *packardii*, and *angustipennis*, the disk of the pronotum has a slightly shadowy to quite black margin that encroaches a little on the upper part of the lateral lobe. Below this the great majority of species have a decidedly pale, more or less crescent-shaped streak which may or may not be bordered with dark shades again on the lower side. The colour of this crescent, the degree to which it extends caudad or cephalad to the adjacent body parts, the presence or absence of markings below it and the nature of such markings when they exist, are all valuable aids the nature of which can be ascertained by a general study of Plates III to VII.

OTHER AIDS TO IDENTIFICATION

Besides colour and structure there are a number of aids to identification that are worthy of special mention. The first of these is a knowledge of distribution records and habitat. The subject as discussed fully by Criddle (12) needs no further elaboration, but is referred to occasionally in the discussion of the species. Secondly, for early species such as *M. confusus* and late species such as *M. gladstoni*, a knowledge of seasonal life-history is advantageous. Last but not least, the usefulness of a properly assembled reference collection cannot be over-emphasized. Such a collection is not as difficult or laborious to build up as it might at first seem. From a variety of habitats weekly collections are made and the material carefully sorted while it is still fresh. As the season advances later instars are encountered and the males at least can be identified by the resemblance of their structural characters to those of the adult. Using these as a guide to colour pattern the species can then be traced back through the various collections even to the first instar. Collection of adults from the same habitats will help to confirm identifications of the nymphs. The same principle applies to the identification of a single collection, for one rarely makes a collection that does not contain a few older individuals of most species and these, being more easily identified, are a useful aid in distinguishing the younger nymphs.

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Introduction

DISCUSSION OF SPECIES

Carothers (3) states that a knowledge of adult grasshoppers will enable one to place an immature specimen in the correct genus and often even species. This statement appears to be largely true, but the use of adult characters in the placement of nymphs of the genus *Melanoplus* is, as already pointed out, limited mostly to the last 1 or 2 instars except in a few species having the general markings of their parents.

Describing the adults of *Melanoplus* and related genera there is a vast literature a discussion of which is beyond the scope of this paper. A knowledge of the fundamental structures can be obtained from many sources, more especially Chopard (4), Walker (59, 60), MacGillivray (34), and Snodgrass (48, 49, 50, 51, 52). Most of the more recent descriptions of species of *Melanoplus* and decisions regarding their synonymy have been made by Mr. Morgan Hebard a very few of whose publications are listed among the references. The work of Blatchley (2) is rather incomplete and out of date as regards synonymy, but it is still a most useful publication, especially for its characterization of the larger groups. Claasson (5) also gives detailed descriptions of *Melanoplus* and the closely related genera. Two papers by Hebard (24, 26) contain concise and very useful keys to many species including all of the *Melanopli* occurring in Manitoba.

The following key, taken from Morse (38), will give a clue as to how the characteristics of the adult may be utilized for separating nymphs of the larger groups:

"A. Antennae ("feelers" on the head) very slender and tapering to a fine point (usually much longer than the body).

B. Colour black or dark brown. Body a little depressed (flattened from above downward). Feet (tarsi—last segment of leg) three-jointed.....Field crickets

C. First joint of hind tarsi with stiff spines above.
Large Black Field-cricket, *Gryllus assimilis*

CC. Without such spines.....Striped Grass-cricket
Small Brown Field-cricket, *Nemobius fasciatus*

BB. Colour pale green, usually with a dark stripe along middle of back. Feet four-jointed. Green, Long-horned or Meadow-grasshoppers.

AA. Antennae shorter than the body, thread-like but not tapering to a fine point. Feet three-jointed.....Common Grasshoppers (short-horned).

D. Face in side view strongly retreating, making a sharp angle with the top of the head (vertex). Collar (pronotum) nearly flat above, its upper surface (disk) meeting the side at an angle marked by a slight ridge (lateral carina).
Slant-faced Grasshoppers

DD. Face in side view rounding smoothly into the top of the head without marked angle at the vertex.

F. Top of collar (disk of pronotum) sloping downward roof-wise, from a median ridge to the low lateral ridges, which diverge strongly backward. Distance between eyes on top of head equalling width of an eye. A robust brown or gray species, mottled with darker, and usually showing a blackish bar across the face on a level with and covering the lower half of the eyes. No prominent projection on the throat between the bases of the front legs in any stage.
Clear-winged Grasshopper, *Camnula pellucida*.

FF. Top of collar (disk of pronotum) curving smoothly downward from the low median ridge into the sides; lateral ridges present only in the adult. Distance between the eyes on top of head much less than width of an eye. In the fifth, fourth, and often in the third stages a prominent spine is noticeable projecting downward between the bases of the front legs (prosternal spine). This cannot usually be made out satisfactorily in the first, second, and often in the third stages.....Spine-throated Grasshoppers."

Morse also describes *M. atlanis (mexicanus)*, *M. bivittatus* and *M. femur-rubrum* and there is a ray of hope in the fact that the characters as

used by him in Maine are useful to-day in Manitoba. But it is realized that, for colour characters especially, those used successfully in one region will not necessarily suffice for the same species elsewhere, nor is it at all likely that the characters used will separate all Manitoba species from all other species of the genus.

In the characterization of the individual species in a later section, detailed colour descriptions are not given for a number of reasons. In the first place the nature of the markings can be gathered much better by reference to the plates, and it is therefore unnecessary to increase the wording and confuse the issue by including cumbersome descriptions. Secondly, and of more importance, the details of the actual colour shades are, as already explained, comparatively unreliable.

No attempt has been made in either the key, the comparative discussion or the plates, to arrange the species according to a "natural" system. Instead, every effort has been directed towards making a comparison of those species which superficially or otherwise resemble each other most nearly and as a result are most easily confused.

Key to Nymphs

The following key is useful as a guide only. In few instances will it separate all individuals of the species listed even when used by one who knows the group reasonably well, and for anyone who has not had an opportunity to make a comparison of a given character in different species it is quite easy to choose the wrong member of a couplet. It is common experience that even the best of keys on the most clearly differentiated material often lead to difficulties in the hands of those unfamiliar with the particular group, and in material as poorly defined as the immature stages of *Melanoplus* the difficulties multiply. For this reason the reader is advised to use the comparisons in the next section rather than the key, at least until he is reasonably familiar with the group. Similarly, it would be unwise to rely on the figures in the plates without first reading the text under "Comparisons of Species".

1. Outer face[1] of hind femur fuscous, broken or not by contrasting light marks, but these when present never cutting completely across fuscous area.....Group I (2)
   Outer face of hind femur either uniformly pale with minute dark spots, or fuscous with 1 or more light bands cutting completely across dark areas.....Group II (11)

Group I

2. Lighter maculations of compound eye sparse, their total area occupying less than one-third of total area of eye.....(3)
   Lighter maculations of compound eye numerous, their total area occupying more than one-third of total area of eye.....(4)
3. Compound eye with 2 distinct transverse light streaks.....*M. keeleri luridus* (Dodge)
   Compound eye with scattered light spots but not transverse streaks *M. dawsoni* (Scud.)
4. Fuscous streak of hind femur not interrupted along either upper or lower margin (see couplet 17 for first and some second instar *M. differentialis*).....(5)
   Fuscous streak of hind femur commonly broken by 1 or 2 pale notches on upper half (7)
5. Compound eye brown to pale brown with small rounded lighter spots uniformly distributed over surface; dark streak on outer face of hind femur confined to upper row of chevrons and upper tips of lower row of chevrons; dark streak on inner face of hind femur rarely broken by transverse lighter band; upper flange of hind femur rarely with dark markings; pronotal crescent present but not always

[1] The outer face of the hind femur refers only to that part marked by chevrons and does not include the flanges.

whitish and if whitish the lighter shade not extending across gena; furculae not present except as minute tubercles in some fifth instar males; fourth and fifth instar females with latero-posterior projections on eighth sternite.
M. bivittatus (Say)

Compound eye brown to fuscous with lighter markings not uniformly distributed (sometimes so in first instar), banding being common; dark streak on outer face of hind femur covering upper and at least one-third of lower row of chevrons; other characters as above or not.....(6)

6. Dark streak on inner face of hind femur continuous; markings contrasting greatly; dark areas extensive and uniform; pronotal crescent almost white and connected with area of similar colour on gena; furculae indicated in males as early as third instar; females without latero-posterior projections on eighth sternite.
M. femur-rubrum femur-rubrum (DeG.)

Dark streak on inner face of hind femur interrupted by transverse light band or bands; markings only moderately contrasting; dark areas commonly mottled; pronotal crescent sometimes present but confined to small area; gena yellowish, faintly mottled with brown; furculae never present; fourth and fifth instar females with latero-posterior projections on eighth sternite.....*M. differentialis* (Thom.)

7. Dominant colour gray or green; fuscous markings few but clearly defined; lower half of compound eye never darker than upper half, the darker markings commonly forming transverse zigzag lines; furculae broad and blunt in third to fifth instar males.....(8)

Dominant colour fuscous or brown; lower half of compound eye darker than upper half or not, the darker markings never zigzag; furculae either narrow and pointed or else lacking.....(9)

8. Dominant colour gray; feeding restricted to *Artemisia cana* Pursh. and possibly closely related species (see couplet 13 for majority of specimens)
M. bowditchi canus Hebard

Dominant colour green; feeding not restricted to one host, rarely or not at all on *Artemisia*.....*M. flavidus flavidus* Scud.

9. Lower half of compound eye distinctly darker than upper half; pronotal crescent almost white and connected with area of similar colour on gena; entire dorsal area pale cream colour and separated sharply from dark lateral areas.....(10)

Lower half of compound eye not distinctly darker than upper half; pronotal crescent usually indicated by a small white spot; gena yellowish with brown spots; dorsal area, if pale, not separated sharply from lateral areas (see couplet 17 for majority of specimens).....*M. mexicanus mexicanus* (Sauss.)
M. bruneri Scud.

10. Tarsi and tibiae pale; dorsal area pale with few or no brown spots; lateral lobe of pronotum below crescent commonly ferruginous with few or no fuscous spots; darker area on posterio-ventral part of gena narrower than lighter area above it
M. islandicus Blatch.

Tarsi and tibiae (at least distal third) fuscous or nearly so; dorsal area pale but dotted with fuscous; lateral lobe of pronotum below crescent spotted with fuscous; darker area on posterio-ventral part of gena as wide as lighter area above it
M. borealis junius (Dodge)

Group II

11. Crescent absent from pronotal lobe; gena and pronotal lobe darkly marked with mottled brown and fuscous, commonly more so than dorsal areas of head and pronotum
Subgroup A.—*M. huroni* Blatch.

Crescent present on pronotal lobe or, if absent or poorly indicated, gena and pronotal lobe with few or no dark markings, at least fewer than dorsal areas.
Subgroups B and C (12)

12. Pronotal crescent absent; brown and fuscous markings when present commonly in the form of small dots; dots on the pronotum, at least, more abundant on dorsal than lateral areas; green, fawn, or gray forms (with few or no dark markings) often predominating.....Subgroup B (13)

Pronotal crescent present but sometimes restricted to small white spot; brown and fuscous markings usually present in larger or smaller patches, and pronotal lobe almost if not quite as dark as disk of pronotum; mostly brown forms, but occasional fawn or green forms never without fuscous patches.....Subgroup C (17)

13. Dominant colour gray; feeding commonly restricted to *Artemisia cana* Pursh. and possibly closely related species; furculae broad and blunt in third to fifth instar males (see couplet 8 for a small percentage of specimens)
M. bowditchi canus Hebard

Dominant colour green, fawn, or brown; general feeders, *Artemisia* species rarely attacked; furculae either narrow and pointed or else lacking.....(14)

14. Restricted in Manitoba to sandy soil of jack pine areas in northern and eastern sections of the province.....*M. stonei* Rehn
Not restricted to such areas.....(15)

15. Occurring rarely in Manitoba except in 2 limited areas: (1) Area bounded by lines through villages of Gretna, Plum Coulee, Jordan, Miami and Haskett. (2) Corner of province southwest of Deloraine, Lauder, Pipestone and Sinclair
M. packardii Scud.

Occurring generally over province.....(16)

16. Dominant colours light brown or fawn; subgenital plate notched or emarginate at tip in fifth instar males and notched or truncate in fourth instar males
M. angustipennis (Dodge)

Dominant colours fawn or green; subgenital plate rounded at tip in fifth instar males, sometimes rounded in fourth instar males but truncate in many specimens
M. foedus foedus Scud.

17. Lower half of compound eye not distinctly darker than upper half, a dark transverse band often faintly indicated at middle of eye; white crescent frequently restricted to a small spot at centre of pronotal lobe; gena usually yellowish and lightly flecked with brown to light brown; tip of subgenital plate notched or emarginate in fourth and fifth instar males.....*M. mexicanus mexicanus* (Sauss.)
M. bruneri Scud.
First and some second instar *M. differentialis* (Thom.)

Lower half of compound eye distinctly darker than upper half, a dark transverse band usually strongly indicated at middle of eye; tip of subgenital plate entire in fourth and fifth instar males.....(18)

18. Pronotal crescent and gena with few or no minute spots of brown or fuscous; fuscous patches on outer face of hind femur confined to upper half, lower margins of patches even and in straight line; species with large areas of pale cream and with smaller areas of strongly contrasting fuscous.....(19)

Pronotal crescent and gena with scattered brown and fuscous dots; fuscous patches on outer face of hind femur encroaching on lower half, lower margins of patches uneven; species with very few pale areas, and these with many fuscous dots...(21)

19. Ventro-posterior area of gena uniformly dusky, the dusky portion as wide as cream coloured streak above and in front of it; lateral lobe of pronotum below crescent uniformly dusky; cerci of fourth and fifth instar males much narrower on distal third than middle third; species not occurring in Manitoba
M. occidentalis occidentalis (Thom.)

Ventro-posterior area of gena same colour (cream) as central area or, if dusky, the dusky portion narrower than cream coloured streak above and in front of it; lateral lobe of pronotum concolourous except for small fuscous spot adjacent to crescent; cerci of fourth and fifth instar males no narrower at widest part of distal third than at middle.....(20)

20. Frontal costa much darker than surrounding areas, especially at ventral end (Plate VIII, fig. 22); cerci of fourth and fifth instar males wider at some portion of distal third than at middle; tip of cerci notched or forked in fifth instar males at least
M. infantilis Scud.

Frontal costa but little darker than surrounding areas (Plate VIII, fig. 23); cerci of fourth and fifth instar males no wider on distal third than at middle; tip of cerci never notched or forked.....*M. gladstoni* (Scud.)

21. Fuscous areas on outer face of hind femur contrasting strongly with the V-shaped cream coloured area cutting across them; transverse bar on compound eye not strongly indicated; cerci of fourth and fifth instar males straight or curved very slightly downward at tip; collected most frequently in bear-berry on sandy soil near conifers; rarely maturing before July 1.....*M. fasciatus* (F. Walk.)

Fuscous areas on outer face of hind femur not solidly coloured; transverse light area diagonal rather than V-shaped; transverse bar on compound eye strongly indicated; cerci of fourth and fifth instar males turned upward and often inward at tip; distributed widely in a variety of habitats; commonly maturing by June 20
M. confusus Scud.

Comparison of Species

Group I

Melanoplus keeleri luridus (Dodge)

M. luridus is a contrastingly black and gray species. No green or other striking variations in colour have been observed. It can be distinguished from all of the 21 species by the 2 median light bands running across the black of the eye (Plate VIII, Figure 2). The light spots occurring on other parts of the eye increase somewhat in the later instars but are always few in number. The broad expanse of gray on the pronotal lobe and gena is quite helpful. The narrowing of the femoral stripe proximally is characteristic of all stages including the adult.

Melanoplus dawsoni (Scud.)

This glossy species is likewise one with very contrasting colours, the lighter shades in fresh specimens being pale cream to yellow. The contrast is maintained throughout but is partly masked in the later stages by a grayish cast somewhat resembling, in appearance only, the "bloom" that occurs on plums and other kinds of fruit. The dark pigment of the eye, with or without a few scattered light spots (Plate VIII, Figure 1), serves as in *luridus* to separate all stages from those of the remaining species. The highly polished nature of the exoskeleton also sets it aside from the rest of the group. The black of the posterior femur is frequently broken in the later instars by a light wedge-shaped mark on the distal half of the upper margin.

Melanoplus femur-rubrum femur-rubrum (DeG.)

M. femur-rubrum in its more typical and abundant form is another species with strongly contrasting black and whitish green or yellowish markings, looking not unlike *dawsoni* in general appearance. The characters already given for that species make them easily separable. The darker forms of *bivittatus* can also be confused with *femur-rubrum*, and the green forms that occur in both species are distinguishable only with care. In *femur-rubrum* as much of the area of the eye is covered with light spots as with dark pigment. There is, however, a strong tendency to banding, the lower half being noticeably darker than the upper part. This usually separates the species quite readily from *bivittatus* except in many first and some second instar individuals where the segregation of light and dark pigments is not as noticeable, making those of *femur-rubrum* very similar to the uniformly spotted, brownish eyes of *bivittatus*. The whitish crescent of the pronotal lobe is always present in the first and second instars at least, and continues part way across the gena; in *bivittatus* the crescent is less pronounced and does not reach the head at all. The black band of the posterior femur is not broken in either species, but whereas in *bivittatus* it barely touches the lower row of chevrons, and close examination shows it to be somewhat irregular along its lower margin, in *femur-rubrum* it covers the upper third of the lower chevrons and has an even ventral margin. In the first instars of the latter species the whole outer face of the femur is commonly black or smoky and 2 dusky spots usually occur on the inside of the upper flange if not on the outside; in *bivittatus* the dark pigment fails to cover the lower chevrons of the proximal two-thirds of the femur, appears very rarely on the upper flange, and still more frequently shows only as a narrow streak as in Plate III, Figure 3.

Separation of the last 2 or 3 instars of the species on a structural basis is a comparatively simple task. The furculae appear in third instar males of *femur-rubrum* and are absent in *bivittatus* except as to 2 minute points in some fifth instar individuals. The male cerci and subgenital plates are distinctly different in at least the last 2 instars (see Plates X and XI). In the fourth and fifth instar females, the presence in *bivittatus* and absence in *femur-rubrum* of the latero-posterior projections on the eighth sternite (Plate II) is quite distinctive.

Melanoplus bivittatus (Say)

M. bivittatus is almost completely described by the above comparison with *femur-rubrum*. The species usually has a quite evident yellowish ground colour which may vary from orange to bright green, the green forms seeming to be more frequent, if not predominant, in years of low population. Except in the greener individuals, the dark markings are generously sprinkled over the body in broken and mottled patches. One outstanding characteristic which serves with practice to separate *bivittatus* from the remainder of the group is the uniform distribution of small rounded light spots on the brown basal colour of the eye. The spots may be either distinctly separated or close enough so as to anastomose but they are always uniformly distributed. The comparison below with *differentialis* completes the characterization of this common pest.

Melanoplus differentialis (Thom.)

The general yellowish-orange ground colour that is common in *differentialis* is similar to, although slightly deeper than, that of *bivittatus*. The dark markings, too, are broken up much the same as in the latter species and perhaps even a little more so. Interestingly enough, the close resemblance so evident in the later stages does not exist in first instar specimens which cannot be satisfactorily distinguished from some forms of *mexicanus*. If the individuals figured in Plate IV, Figures 7 and 8, are compared, it will be observed that there is a greater contrast in some of the lighter and darker markings. This, however, happens to be quite unreliable as a general means of separation. Neither can the antennal differences nor any other differences that are observable in the two figures be relied upon, with the possible exception of one. This is the basal streak of the hind femur, and even it has definite limitations. In *differentialis* the streak is relatively heavier than in *mexicanus* and its margins are more nearly entire. There is a tendency, too, in the former species, for the streak to be continued across the lighter area distad to it. This also tends to occur in the darker forms of *mexicanus*, but in these same individuals, as shown in Figure 6 of Plate IV, the dark pigment fills in below the basal streak, a condition not common to *differentialis* unless perhaps in melanistic forms which the writer has not encountered. In the later stages, characteristically as in Plate VI, Figure 5, the black femoral stripe is not infrequently weakened at a point a little beyond the middle, but in the material studied this lighter area rarely causes a complete interruption. In any event the later stages can usually be separated from *bivittatus* by a combination of characters: in *differentialis* the spots on the eye are not uniformly distributed, the white crescent is either absent or very obscure, the femoral stripe covers

at least a third of the lower row of chevrons, there are two dark marks on the upper flange of the same member, and these form two dark bars across the femur on the inside, *bivittatus* commonly differing in all these respects.

The last 2 instars can be separated on structural characters. The best of these are the male cerci shown in Plate XI, Figures 13A-D and 14A-D. In the fourth and fifth instar[1] females the latero-posterior projections of *differentialis* are as long as the egg-guide while in *bivittatus* they are approximately half as long as that structure. (Compare Figure 18B of Plate XII with Figure 5B of Plate II).

Melanoplus flavidus flavidus Scud.

The general colouring of *flavidus* is quite distinctive when specimens are fresh, but of doubtful value in preserved material. The early stages are pale green to cream and the later stages commonly bright green, the green being present in several shades. Dark markings are few but sharply defined. The black stripe on the hind femur is quite narrow, especially towards the ends, and usually has 1 or 2 emarginations on the upper side. Lighter markings predominate on the eye, the darker lines having a more or less zigzag form, and, if any difference exists at all, there is more dark pigment in the upper than the lower half. The variegated green, the emarginations and narrowness of the femoral stripe, and the nature of the eye, all serve to separate this species from the green forms of *bivittatus* and *femur-rubrum* which it resembles considerably.

The furculae can be seen in the third instar as 2 slight but broad swellings. In the fourth and fifth instars (Plate IX, Figures 4C and 4D) they are quite distinctive, *bowditchi canus* being the only species having very similar structures. The cerci of the males differ considerably from *bivittatus* but only slightly from *femur-rubrum*. The subgenital plate differs more from the latter species. The third valvulae of the female are of the *angustipennis* type, those of the other 2 species resembling *differentialis* (Plate XII, Figures 18 and 19).

Melanoplus borealis junius (Dodge)

In *borealis junius* the ground colour varies considerably from pale cream to light brown. Dark brown or black pigment is present in large patches and is scattered over the remaining areas in numerous small dots. The dorsal area is commonly light coloured and sharply delimited from the sides. In the first instar the black pigment covers nearly the whole specimen except the back (Plate III, Figure 6). The femoral stripe covers the greater portion of the outer face of the femur but is broken in 1 or 2 places on the upper half. The eye contains light spots over its entire area but the lower half is considerably darker than the upper half (Plate VIII, Figure 8). The white crescent stands out in sharp contrast to the other markings. The species resembles *femur-rubrum* in some degree but they can be separated by means of the broad dorsal stripe, the greater degree of spotting, the light mark on the femoral stripe, and the stronger differentiation of the eye. The resemblance to *islandicus* is even greater. The differences are listed under that species.

The genital structure of both male and female nymphs are not strikingly different from those of *femur-rubrum*.

[1] These are in reality the fifth and sixth instars of this species, but since they correspond more closely in arrangement of the wing pads and apparently in general maturity to the fourth and fifth instars of the remaining species, they are so numbered for the sake of uniformity.

Melanoplus islandicus Blatch.[1]

M. islandicus very closely resembles *borealis junius* in the major characteristics of colour pattern including the dorsal stripe, femoral stripe, pronotal crescent, and eye marking. It is, however, lighter coloured with very few of the minute black spots so characteristic of the latter species. There is very little dark pigment below the crescent and that which is present is more tan than brown. Tan commonly borders the dorsal side of the crescent also but gives way to dark brown or black dorsally. The pale dorsal area is sharply differentiated from the lateral. Tan also forms a portion of the darker pigment on the abdomen. The femoral stripe and the eye markings do not safely separate the 2 species, but the former narrows more strongly in *islandicus* on the proximal upper margin, and the eye markings are more strongly contrasting and have a greater tendency to form a bar. As may be ascertained from the plates, the pale area of the gena is distinctly wider in *islandicus*, and the tibia and tarsus are pale in that species and dark in *borealis junius*.

The female structures are of the *femur-rubrum* type but otherwise not particularly distinctive. Neither are the fourth instar male structures of special value. No fifth instar males were secured for study.

The species is restricted in Manitoba to thin stands of jack pine, especially if blueberry and bearberry are also present.

Group IIA

Melanoplus huroni Blatch.

The few specimens studied of this rather large, clumsy, dark brown to dark gray species are quite distinctive. The sides of the head and pronotal lobes are quite darkly pigmented, commonly more so than the dorsal areas of the same body parts. There is no evidence of a pronotal crescent or spot. The lower part of the eye is much darker than the upper part. This combination of markings, or absence of markings, differentiates this species from all the others studied.

Except for the first, second, and a single fourth instar, male nymphs were not available for study. The female genitalia were found to be of the *femur-rubrum* type.

The species is rare in Manitoba, occurring in the same type of habitat as *islandicus*.

Group IIB

The species in this group are not clearly differentiated, especially in the early instars, and the fawn and green forms occurring so frequently in *angustipennis*, *foedus*, and *packardii* are practically indistinguishable.

Melanoplus bowditchi canus Hebard

The individuals of *bowditchi canus* used in this study were progeny of adults obtained from Alberta. The fact that these are not being compared with Alberta forms of the other species should be borne in mind. The more common type of individual has a general grayish cast that in itself tends to distinguish it from the other 21 species discussed, but there are variations from this especially in the first instar. Dark markings are usually few except for the scattering of small spots over most areas of the

[1] This was formerly a subspecies of *mancus* but was given species rank by Hebard (27).

body. In some individuals they are a little larger and more distinct, approaching in a moderate degree the markings of *flavidus*. The markings of the eye are also very similar to those of *flavidus* but average slightly darker in the specimens on hand. The markings on the outer face of the hind femur are never as dark as they are on that species and most frequently are quite pale, or else show the transverse lighter band common to darker members of the rest of Group IIB. The stripe on the inside of the femur, however, is dark, and though in a few of the older nymphs there is a suggestion of a transverse light band, the dark stripe is never distinctly broken as it is in the other four species (Plates III to VII). There is no white crescent on the pronotal lobe but a brightening of this area, again somewhat as in *flavidus*, is characteristic. Except for the somewhat greater contrast in markings and the stripe on the inside of the hind femur, there are many individuals especially in the first instar that cannot be distinguished with certainty from some forms of the other 4 species.

Structurally, as would be expected, *bowditchi canus* resembles *flavidus* closely and therefore the males differ considerably from the rest of the group, more especially in the nature of the furculae. These are, if anything, slightly wider than those of *flavidus*. There are no latero-posterior projections on the eighth sternite of the females of *bowditchi* canus but these are present in the other species of Group IIB.

The writer has not seen this species in its habitat but it is reported by Criddle (12) to feed entirely on *Artemisia cana* Pursh. This is probably true in nature, but contrary to Criddle's findings it was reared on wheat, dandelion, and wandering jew, at the University of Minnesota, and adults were induced to produce quantities of fertile eggs when they were fed only on *A. ludoviciana* Nutt.

Melanoplus angustipennis (Dodge)

M. angustipennis is characterized fairly completely by the description of the group. It is an extremely variable species. Pale fawn and green specimens, with a scattering of minute dark spots or with no trace at all of dark markings, are common. However, forms somewhat darker than *foedus* and *packardii* are the rule. In these the dorsum is more contrastingly dark, the sides of the pronotal lobes are more heavily spotted, and the outer face of the posterior femur more strongly barred. But these characteristics do not separate *angustipennis* from *stonei* nor do they differentiate it sharply from some forms of the other 2 species. The slight indication of a small whitish spot on the pronotal lobe, in the usual position of the white crescent, makes separation from *mexicanus* also rather difficult. It can usually be accomplished, however, by taking into consideration the greater tendency to spottiness of the lateral lobe of the pronotum in *angustipennis* and the greater contrast between this area and the darker pronotal disc.

The female genitalia (Plate XII, Figures 19A and B) are not differentiated from any of the remaining members of the group, but those of the fifth instar, and sometimes the fourth, exhibit the latero-posterior projections not present in *bowditchi canus*. The cerci are narrower than in the remaining 3 species but the difference is too slight to be of much value. The emargination at the tip of the subgenital plate separates fifth instar males from the other species but is of only moderate use in the fourth instar.

Melanoplus stonei Rehn[1]

M. stonei averages darker than the other species with slightly more contrast between the lighter and darker shades. Otherwise there is no specific pattern that differentiates it from the darker forms of *angustipennis*. Light forms occur but the series on hand is not large enough to permit an estimation as to the probable percentage. Specimens without some quantity of dark pigment have not been observed.

Fifth instar males have not been examined but judging from the adults it is not likely that there would be any constant structural difference between *stonei* and the next two species.

This is not a common species in Manitoba and up to the present time has been obtained only in pine woods associated with *huroni* and *islandicus*.

Melanoplus foedus foedus Scud.

Light green appears to be the dominant colour form in *foedus*, but fawn individuals, with or without the scattering of minute dark spots, are frequent. Specimens with a darker cast to the dorsum and a definite dark pattern on the posterior femur are also numerous. Any differences which might serve in some degree to separate *foedus* from the other 4 species are mentioned in the discussion of those species.

Melanoplus packardii Scud.

Green and fawn forms seem to be dominant in this species also. In general there appears to be a denser sprinkling of minute round spots of dark pigment, but otherwise the general appearance is as in *foedus*. In all the specimens examined the eye showed little or no tendency to barring but there were 3 or 4 shades of pigment rather than the usual 2. If this proved to be a constant characteristic it would serve to distinguish the majority of individuals of *packardii* from the rest of the group. However, the close resemblance of this species to the others has made field material altogether too unreliable, and it is felt that a large series of reared individuals should be examined before a definite statement about this eye character can be made.

Although *angustipennis*, *foedus*, and *packardii* occur in cultivated areas of light soil, *packardii* does not appear to be as widely distributed in Manitoba as are the other two species. Rehn and Hebard (44) and Hebard (22) have reported it as occurring at Aweme, Manitoba, but this was before the appearance of Hubbell's (31) paper on the internal genitalia of the males. In a later publication Hebard (23) corrects conflicting reports of *foedus* and *packardii* in Montana. *M. foedus* is mentioned in this paper as occurring at Aweme, Manitoba, but the distribution of *packardii* in the province is not given. From the material in the Brandon laboratory it would appear that *packardii* occurs but rarely in Manitoba except in a small area in the corner of the province southwest of the towns of Deloraine, Lauder, Pipestone, and Sinclair, and in another small area bounded by lines joining Gretna, Plum Coulee, Jordan, Miami, and Haskett. In both these areas the lightest soil was most favoured.

[1] The only fourth instar male available (Plate VII, Figure 2) was considerably paler than the other specimens on hand, and the difference in contrast of the first instar (Plate V, Figure 2) is due less to the specimen than to the fact that it was taken on a more contrasting film which unfortunately could not be secured again after the original supply was exhausted.

Group IIC

Five of the 7 species included here answer the group description quite closely. The other two, *mexicanus* and *bruneri*, are extremely variable. As in some of the other groups the first instar specimens are often very difficult to separate.

Melanoplus mexicanus mexicanus (Sauss.)

The nymphs of *mexicanus* are extremely variable. The ground colour may be cream, yellowish-orange, or green, or the dark brown pigment may be so extensive as to block out the ground colour almost entirely. Dark markings are present even in the green specimens. The femoral stripe is commonly broken by a light band as in Plate IV, Figure 7, and Plate VII, Figure 12, but in the darker individuals the transverse band is limited to a pale spot as in Plate IV, Figure 6. Thus the dark individuals would find their way into Group I, but they can be separated from the members of that group by the reduction of the pronotal crescent to a mere spot in *mexicanus* and by the more distinctive eye characters of the other species. In *mexicanus* the eye is weakly barred in most specimens, with very little difference in degree of pigmentation above and below the bar. The white pronotal spot common to most dark individuals becomes a whitish crescent in the lighter forms. This frequently appears to encroach on the gena but this latter area usually is spotted lightly with brown, or if spots are absent then the area is noticeably duller than the crescent. *M. confusus* closely resembles some of the colour forms, but the bar of the eye in *mexicanus* is less strongly indicated and the dark pigment is more uniformly distributed. The resemblance to first instar *differentialis* is discussed under that species. Similar comparisons appear under the heading of *angustipennis* which hold for *stonei* as well.

The female genitalia are the same as described for *femur-rubrum*. The male genitalia are of value in the fourth and fifth instars. The notch at the tip of the subgenital plate is particularly useful, being duplicated only in *bruneri* and to some extent in *angustipennis*. The furculae are present and of moderate length (Plate IX, Figures 3C and 3D). The cerci differ from all other members of the group except *bruneri*.

Melanoplus bruneri Scud.

This species has been found to resemble in every respect the darker forms, at least, of *mexicanus*. It does not, however, infest fields, but prefers moderately open, shrubby locations in treed areas, and hence can be confused only with such individuals of *mexicanus* as are taken in that particular habitat.

Melanoplus confusus Scud.

This species closely resembles the less extreme forms of *mexicanus*. The ground colour is commonly buff to light brown, the dark brown and black pigment being generously distributed in large patches and small spots. Green forms have not been encountered during the period of the present study. The barring of the eye is more evident than in either *mexicanus* or *fasciatus*, but in the latter there is considerably more dark

pigment below the bar than above it, just as in *confusus*. The whitish pronotal crescent encroaches somewhat on the gena which is usually slightly darker in ground colour and contains a sprinkling of light brown spots.

The third valvulae of the ovipositor resemble those of *angustipennis* in having a high, angulate shoulder, and are therefore of some use in distinguishing fifth instar females, but there are no projections on the eighth sternite. Minute furculae are present in the fourth and fifth instar males. The cerci, bent dorsad and mesad at the tip (Plate XI, Figure 12A-D) differentiate the last 2 instars from the same stages of the other 6 species.

M. confusus is usually the first species to hatch in the spring, third instar individuals being encountered when *mexicanus* begins to hatch.

Melanoplus fasciatus (F. Walk.)

M. fasciatus does not differ greatly from *confusus*. The ground colour is more commonly pale yellow to cream, and reddish brown tints frequently mingle with the fuscous and black pigments. The dark pigment on the hind femur is commonly quite heavy, the cream coloured light areas showing up in strong contrast. This density of the pigment together with the tendency it exhibits to extend across the lower as well as the upper half of the femur, thus taking a V-shaped form, is typical of *fasciatus* but requires considerable practice before it can be used satisfactorily as a distinguishing character. The eye is not strongly barred, often not at all, but the lower part is much darker than the upper. The pronotal crescent is clearly indicated but on the gena it is sometimes moderately spotted with pale brown. It will be seen, then, that the species cannot be clearly distinguished from *confusus*. With practice, however, the difference in the barring of the eye, the greater contrast in the femoral and lateral markings, and the greater richness of colour, can be used with considerable degree of assurance.

The adult females commonly have a minute latero-posterior projection on the eighth sternite but this is of no value in the nymphs. The female genitalia in general are of the *femur-rubrum* type. Furculae are not present in the males. The cerci of this sex, are not very specific in shape but are quite long (Plate IX, Figures 2A-D).

The writer has found this species only in the pine woods (blueberry-bearberry habitat) and in bearberry patches adjacent to spruce trees, but Criddle (12) states that it is not confined to such locations.

Melanoplus infantilis Scud.

This species, together with *gladstoni* and to a large extent *occidentalis*, is strikingly characterized by the strong contrast of the darker markings against an expanse of pale cream ground colour, and by the almost complete absence of minute dark spots. The fuscous on the outer face of the posterior femur is regularly confined to the upper half. The eye is barred and noticeably darker below than above the bar. The pronotal crescent is margined by black above and by a few dark spots below but otherwise is not differentiated from the basal colour. The gena is unmarked by dark pigment. The only way in which the various instars of *infantilis* can be

separated with any degree of assurance from those of *gladstoni* is by the greater area of dark pigment occurring in the latter species in all parts except the frontal costa and adjacent edge of the clypeus which are darker in *infantilis* (Compare Figures 22 and 23 of Plate VIII.). Even this characteristic fails in a small percentage of individuals.

The female nymphs cannot be separated satisfactorily on a structural basis but the fourth and fifth instar male cerci are quite distinctive. In *infantilis* the tip is noticeably forked. This is not so evident in the fourth instar but the rudiment of the upper fork shows up as a definite angle, the same point in *gladstoni* being rounded; the lower margin is distinctly curved in the former species and almost straight in the latter. Moreover, in *infantilis* the cerci are slightly wider on the distal third than at the middle, while in *gladstoni* they are not.

Melanoplus gladstoni (Scud.)

M. glads.oni, as mentioned above, is strikingly similar to *infantilis*. It has a greater total area of dark pigment on the average and a more sharply defined bar on the eye, but the slight variation in these characters in both species renders them unsafe for use in diagnosis. The lower portion of the gena is occasionally rather dull. The markings of the frontal costa and usefulness of male genitalia have already been discussed.

This species develops much later than *infantilis*. Whereas the members of the latter species are nearly all mature by the end of June, fourth and fifth and occasionally third instar specimens of *gladstoni* can still be secured in early August.

Melanoplus occidentalis occidentalis (Thom.)

The nymphs of *occidentalis* were secured from adults collected in Alberta and it is perhaps unwise to compare them with Manitoba species. If this be permitted, however, it must be said that there is nothing in the colour pattern to separate this species sharply from *gladstoni* and *infantilis*. (The discoloration shown in Figure 11 of Plate VII was caused by the preservative). The femoral markings and eye character, within the limits of individual variation, are identical to those of the other species. On the average the darker shades cover a larger area and the pronotal crescent is commonly more sharply defined.

The female structures were not studied but, as shown in Plate XII, Figures 17A and B, the broad base of the cerci narrowing sharply backward and upward to the tip separates fourth and fifth instar males of *occidentalis* quite distinctly from those of the other 2 species.

TENTATIVE KEY TO ADULT FEMALES

The writer finds himself in agreement with Hebard (26) that "no satisfactory key for separating females of the species of *Melanoplus* can yet be supplied". The characters given in the following key, however, have been found very useful for the separation of females in Manitoba and can be applied to some extent to those of the fifth instar. For this reason it has been included here even though admittedly imperfect and not directly a part of the subject matter of this study.

Most of the characters have already been discussed in connection with the identification of nymphs. It might be well, however, to point out once more that many characters are not entirely constant, and frequently it is necessary to employ several in order to reach a maximum of accuracy. The first 2 major characters, wing length and shape of the upper valves of the ovipositor, require practice before they can be used with confidence, and since long-winged individuals are not uncommon in *fasciatus*, *borealis junius*, and *dawsoni* (especially *dawsoni* in Manitoba), this character does not place every individual of those species in its proper group. The two main types of upper valvulae are shown in Plate XII, Figures 18A and 19A, the former being the type with the rounded shoulder and the latter the high, square-shouldered type. Occasionally, however, (e.g., in *mexicanus*) the serrations of the rounded shoulder stand out sufficiently to resemble much too closely the second type, making it difficult to distinguish them until one has become reasonably familiar with the character. The light coloured mark at the base of the antenna, so useful in separating some species, is not usable in nymphs and is not entirely constant in adults. It begins inside and just below the antenna and curves, when continuous, upward and outward above the antenna. The remaining characters have already been fully discussed.

Keys to adult females of the genus *Melanoplus* have appeared before. A key to 11 species was published by Morse in 1898 (36), and again in 1920 (37) and reproduced in part by Walden (58). A key to the Montana species was issued by Mills and Pepper in 1938 (35).

M. differentialis is the only species of those treated below that does not occur in the province. No attempt at a "natural" arrangement has been made, nor is it intended that the key should separate all 19 species from other species not included.

1. Brachypterous species (tegmina and wings commonly shorter than abdomen).....(2)
   Macropterous species (tegmina and wings commonly extending beyond tip of abdomen).....(6)
2. Wings rounded at tip, very small; posterior margin of pronotum broadly rounded, margin of disk directly in line with margins of lateral lobes; small sylvan species confined mostly to areas of jack pine in Manitoba.....*M. islandicus* Blatch.
   Wings pointed at tip, variable in size; posterior margin of pronotal disk variable but not directly in line with posterior margin of lateral lobes.....(3)
3. Metasternal lobes separated by a distance at least equal their length; eyes separated at vertex by a distance of one and one-third times width of frontal costa at median ocellus; light mark at base of antenna broad, conspicuous, and continuous; large sylvan species associated with *islandicus*.....*M. huroni* Blatch.
   Metasternal lobes separated by a distance of less than their length; eyes separated at vertex by a distance not greater than width of frontal costa at median ocellus; light mark at base of antenna usually interrupted at centre, and if not then narrow and inconspicuous.....(4)
4. Prongs of upper valvulae almost straight, their dorsal edges parallel with main axis of valvulae; latero-posterior projections of eight sternite absent; abdomen not ringed with shining black.....*M. borealis junius* (Dodge)
   Prongs of upper valvulae distinctly curved.....(5)
5. Latero-posterior projections present on eighth sternite but very small; abdomen not ringed with shining black.....*M. fasciatus* (F. Walker)
   Latero-posterior projections lacking on eighth sternite; abdomen ringed with shining black.....*M. dawsoni* (Scud.)
6. Upper valvulae with high shoulders approximating a right angle (Plate XII, Figure 19A).....(7)
   Upper valvulae with rounded shoulders, or if approximating a right angle then distinctly serrate and shoulders not clearly defined.....(11)

7. Latero-posterior projections of eighth sternite lacking.....(8)
Latero-posterior projections present on eighth sternite.....(9)

8. Prongs of upper valvulae short and not strongly curved; prosternal tubercle blunt with sides subparallel; light mark near base of antennae broad and continuous; longitudinal marks on outer face of posterior femur broken by transverse light marks.....*M. confusus* Scud.
Prongs of upper valvulae elongate and strongly curved; prosternal tubercle more or less pointed with sides convergent; light mark near base of antenna rarely continuous and if so then narrow; longitudinal marks on outer face of hind femur continuous
M. flavidus flavidus Scud.

9. Length to tip of abdomen less than twenty-five millimetres; latero-posterior projections of eighth sternite small and inconspicuous; structures in general delicate
M. angustipennis (Dodge)
Length more than 25 millimetres; latero-posterior projections of eighth sternite quite distinct; structures in general more robust.....(10)

10. Tibiae mostly pink; general colour dark brown; contrastingly pale transverse marks on outer face of hind femur; confined to pine woods area in association with *M. islandicus*, etc.....*M. stonei* Rehn
Tibiae mostly glaucous; general colour light brown to gray-brown; transverse pale marks on outer face of hind femur either absent or inconspicuous
M. foedus foedus Scud.
M. packardii Scud.

11. Latero-posterior projections present on eighth sternite.....(12)
Latero-posterior projections of eighth sternite lacking.....(14)

12. Length to tip of abdomen less than 25 millimetres; latero-posterior projections of eighth sternite less than half as long as egg guide; general colour fuscous with innumerable minute gray maculations.....*M. gladstoni* (Scud.)
Length to tip of abdomen commonly much more than 25 millimetres; latero-posterior projections of eighth sternite at least half as long as egg guide; general colour yellow with sharply contrasting fuscous markings.....(13)

13. Latero-posterior projections half as long as egg guide; pronotal disk bordered by yellow stripes that continue on the tegmina; fuscous stripe on outer face of hind femur continuous and confined to upper half.....*M. bivittatus* (Say)
Latero-posterior projections as long as egg guide; pronotal disk and tegmina without yellow stripes; fuscous on outer face of hind femur commonly replaced by yellow on posterior margin of each chevron, and always encroaching on lower half of femur.....*M. differentialis* (Thom.)

14. Lighter mark near base of antenna continuous; outer face of hind femur without transverse light bands or spots.....(15)
Lighter mark near base of antenna interrupted at middle; outer face of hind femur with transverse light bands or spots.....(16)

15. Outer face of hind femur covered with heavy fuscous, lighter marks occasionally encroaching slightly on upper margin; prongs of upper valvulae curved but slightly; prosternal tubercle of medium length, sides slightly to distinctly converging
M. keeleri luridus (Dodge)
Outer face of hind femur typically bluish gray; prongs of upper valvulae strongly curved; prosternal tubercle long, blunt, sides subparallel on distal third, and pointing well back to hide rest of sternum; cerci with concave sides tapering to slender tip (see *mexicanus*).....*M. femur-rubrum femur-rubrum* (DeG.)

16. Length to tip of abdomen usually much more than 20 millimetres.....(17)
Length less than 20 millimetres.....(18)

17. Distribution general; prosternal tubercle commonly short, vertical at least posteriorly, sides distinctly converging, tip more or less pointed; cerci comparatively broad, sides convex (see *femur-rubrum*).....*M. mexicanus mexicanus* (Sauss.)
Confined to shrubby or wooded areas; otherwise not clearly differentiated from *mexicanus*.....*M. brunneri* Scud.

18. Caudal tibiae pink; general colour dark brown to fuscous above, bright yellow beneath; comparatively robust.....*M. dawsoni* (Scud.)

19. Caudal tibiae glaucous; general colour brown to yellowish brown above, pale yellow or cream beneath; comparatively slender and delicately constructed
M. infantilis Scud.

SUMMARY

Twenty-one species of *Melanoplus*, 18 of them from Manitoba, are described and compared.

A few of these can be identified in all instars by means of a single characteristic. A few others cannot be separated at all, or at best only in their more typical form. With care, however, the majority can be distinguished on the basis of a combination of colour markings, structural features, and other characteristics.

In all except a few species, the later instars are the more easily identified, first instar specimens nearly always offering considerable difficulty.

No structural characters have been discovered that are diagnostic in the first 2 instars. A few third instar males can be identified by means of such characters, as can also most males of the fourth and fifth instars. Fifth instar females, and to a lesser extent the fourth, can usually be *grouped* quite satisfactorily by means of structure but can rarely be identified *to species* on that basis.

Differences in colour are of moderate value in a few species but are unreliable in the majority of species.

Colour pattern, although more or less variable depending on the species, is surprisingly reliable in most instances and is the only means of characterizing all instars and both sexes on a uniform basis.

The most useful patterns are those on the posterior femora, the lateral lobes of the pronotum, the genae, and the compound eyes. The relative proportion and manner of distribution of the light and dark pigments as a whole is also of definite value.

A knowledge of seasonal life-history, distribution, habitat, and food preferences, sometimes makes possible the separation of species otherwise indistinguishable.

The value of a properly preserved reference collection cannot be overemphasized. An excellent series can be built up by weekly collections in selected habitats, the earlier instars being identified by comparison with the later stages.

The sexes are readily differentiated in all stages, but it is possible in the first instar to overlook the rudiments of the lower valvulae, and when this is done all specimens appear to be males.

The number of antennal segments serve best to distinguish the first three normal instars, and the nature of the wing pads differentiates the fourth and fifth instars from each other and from the earlier stages.

A tentative key to 19 species of adult females is included.

It is hoped that the work may be continued and expanded. Suggestions are given as to structures that are deserving of further study.

ACKNOWLEDGMENTS

It is with pleasure that the writer acknowledges the kindly advice and generous assistance of those with whom he was associated during the assembling and study of the material and the preparation of this paper.

The work was done under the direction of Professor A. G. Ruggles of the Entomological Division, University of Minnesota. His many excellent suggestions as well as those of Dr. W. A. Riley, Dr. C. E. Mickel, and Dr. A. A. Granovsky are gratefully acknowledged.

Considerable material and much valuable advice were received from Dr. R. D. Bird, the writer's senior officer at Brandon, Manitoba. In the preparation of illustrations Dr. Bird made all of the 164 exposures and gave freely of his time and experience generally in all phases of the photographic work.

Thanks are also due Mr. Morgan Hebard for identifying adult grasshoppers, Dr. M. H. Haydak for translating Russian papers on grasshopper nymphs, Dr. C. E. Mickel for obtaining copies of the Russian papers, and Dr. Wm. P. Hayes for furnishing a list of publications containing keys to immature Orthoptera.

The excellent work done by Mr. Stuart Criddle at the Treesbank field station in tending the breeding stock, eggs, and nymphs, during the summers of 1935 to 1938, inclusive, has had an important bearing on the rapidity with which material was assembled for study.

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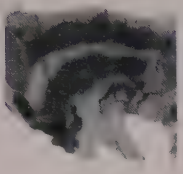
Plate I. Development of Wing Pads (×11).

Figures 1–5. Instars 1–5 of *M. femur-rubrum femur-rubrum* (DeG.).
Figure 6. Fifth instar of *M. islandicus* Blatch.



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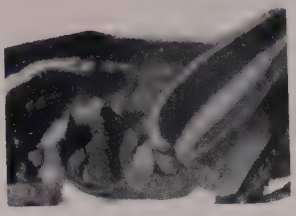

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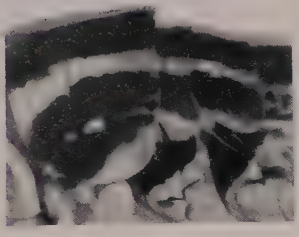

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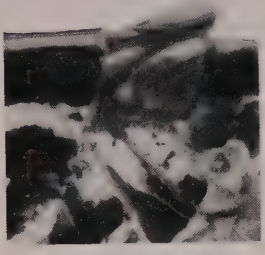

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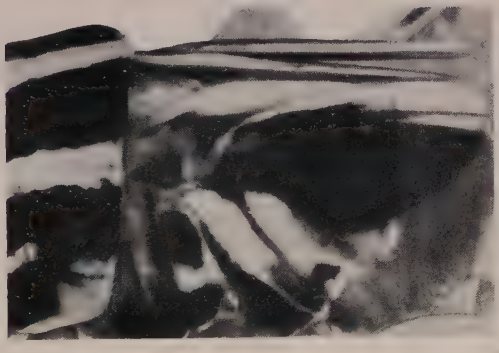

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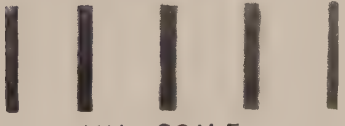

MM. SCALE

PLATE II. Development of Subgenital Plate and Ovipositor (× 11).

FIGURES 1A–5A. ♂♂ of *M. bivittatus* (Say).
FIGURES 1B–5B. ♀♀ of *M. bivittatus* (Say).
FIGURES 1C–5C. ♂♂ of *M. femur-rubrum femur-rubrum* (DeG.).
FIGURES 1D–5D. ♀♀ of *M. femur-rubrum femur-rubrum* (DeG.).

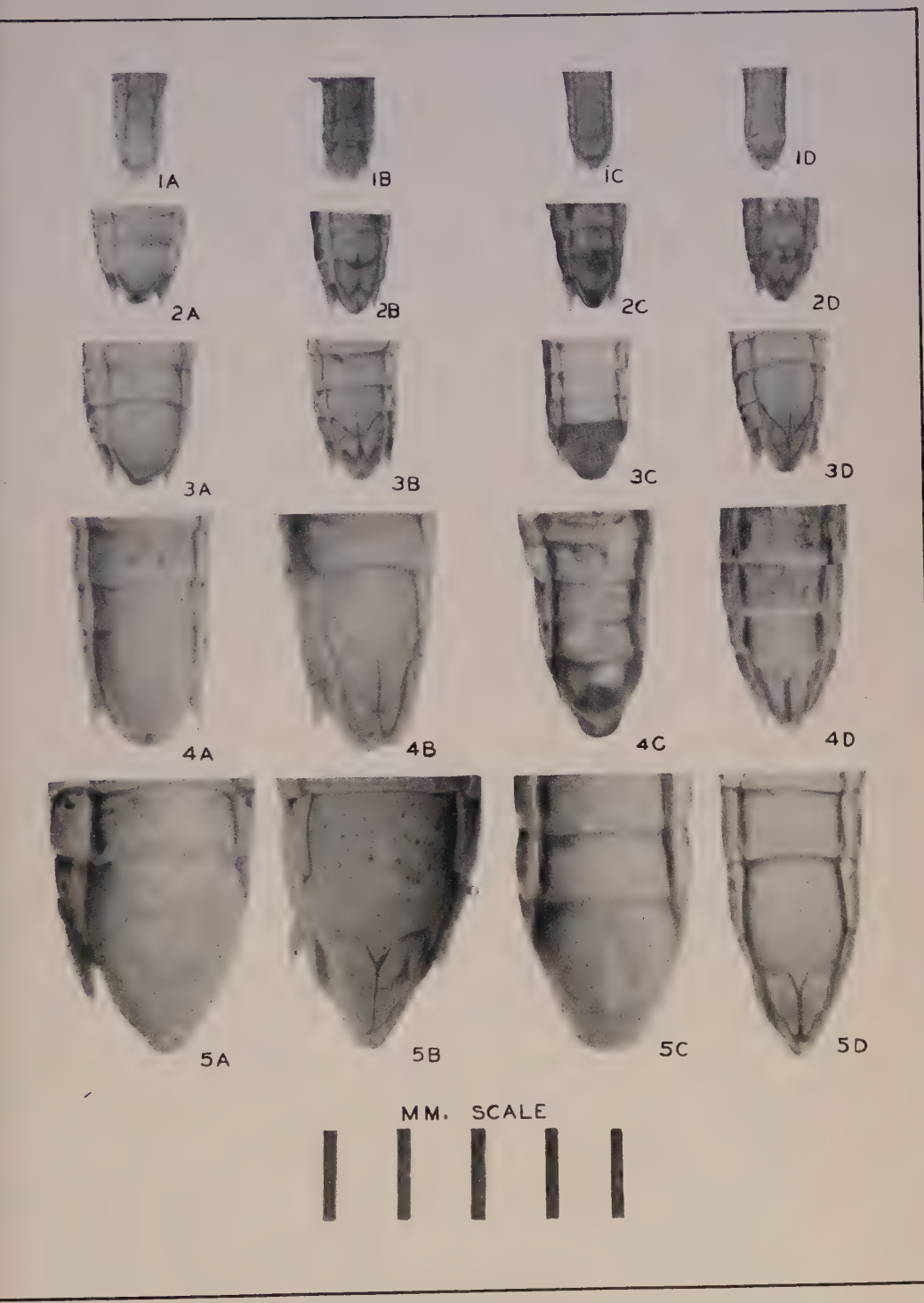
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PLATE III*. First Instar Nymphs (× 9).

FIGURE 1. *M. keeleri luridus* (Dodge). Preserved ♀.
FIGURE 2. *M. dawsoni* (Scud.). Preserved ♀.
FIGURE 3. *M. bivittatus* (Say). Preserved ♀.
FIGURE 4. *M. femur-rubrum femur-rubrum* (De G.). Preserved ♀.
FIGURE 5. *M. islandicus* Blatch. Preserved ♂.
FIGURE 6. *M. borealis junius* (Dodge). Fresh ♀.
FIGURE 7. *M. bowditchi canus* Hebard. Fresh ♀.
FIGURE 8. *M. flavidus flavidus* Scud. Fresh ♀.

* In photographing the specimens shown as Figure 6 of this plate, Figure 5 of Plate IV, and Figures 1 and 2 of Plate V a more contrasting type of film was used. Unfortunately when the supply was exhausted no more of this type could be procured. This should be borne in mind when these figures are compared with any of the remaining ones.

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PLATE IV. First Instar Nymphs (× 9).

FIGURE 1. *M. gladstoni* (Scud.). Fresh ♀.
FIGURE 2. *M. infantilis* Scud. Preserved ♀.
FIGURE 3. *M. occidentalis occidentalis* (Thom.). Preserved ♀.
FIGURE 4. *M. huroni* Blatch. Preserved ♀.
FIGURE 5. *M. bruneri* Scud. Fresh ♀.
FIGURE 6. *M. mexicanus mexicanus* (Sauss.). Preserved ♀.
FIGURE 7. *M. mexicanus mexicanus* (Sauss.). Fresh ♀.
FIGURE 8. *M. differentialis* (Thom.). Fresh ♀.

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PLATE V. First Instar Nymphs (× 9).

FIGURE 1. *M. confusus* Scud. Fresh ♀.
FIGURE 2. *M. stonei* Rehn. Fresh ♀.
FIGURE 3. *M. foedus foedus* Scud. Fresh ♀.
FIGURE 4. *M. fasciatus* (F. Walk.). Fresh ♂.
FIGURE 5. *M. angustipennis* (Dodge). Fresh ♂.
FIGURE 6. *M. packardii* Scud. Fresh ♀.

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PLATE VI. Fourth Instar Males (× 3) (Preserved material).

FIGURE 1. *M. keeleri luridus* (Dodge).
FIGURE 2. *M. dawsoni* (Scudder).
FIGURE 3. *M. femur-rubrum femur-rubrum* (DeG.).
FIGURE 4. *M. bivittatus* (Say).
FIGURE 5. *M. differentialis* (Thom.).
FIGURE 6. *M. islandicus* Blatch.
FIGURE 7. *M. borealis junius* (Dodge).
FIGURE 8. *M. bowditchi canus* Hebard.
FIGURE 9. *M. flavidus flavidus* Scud.

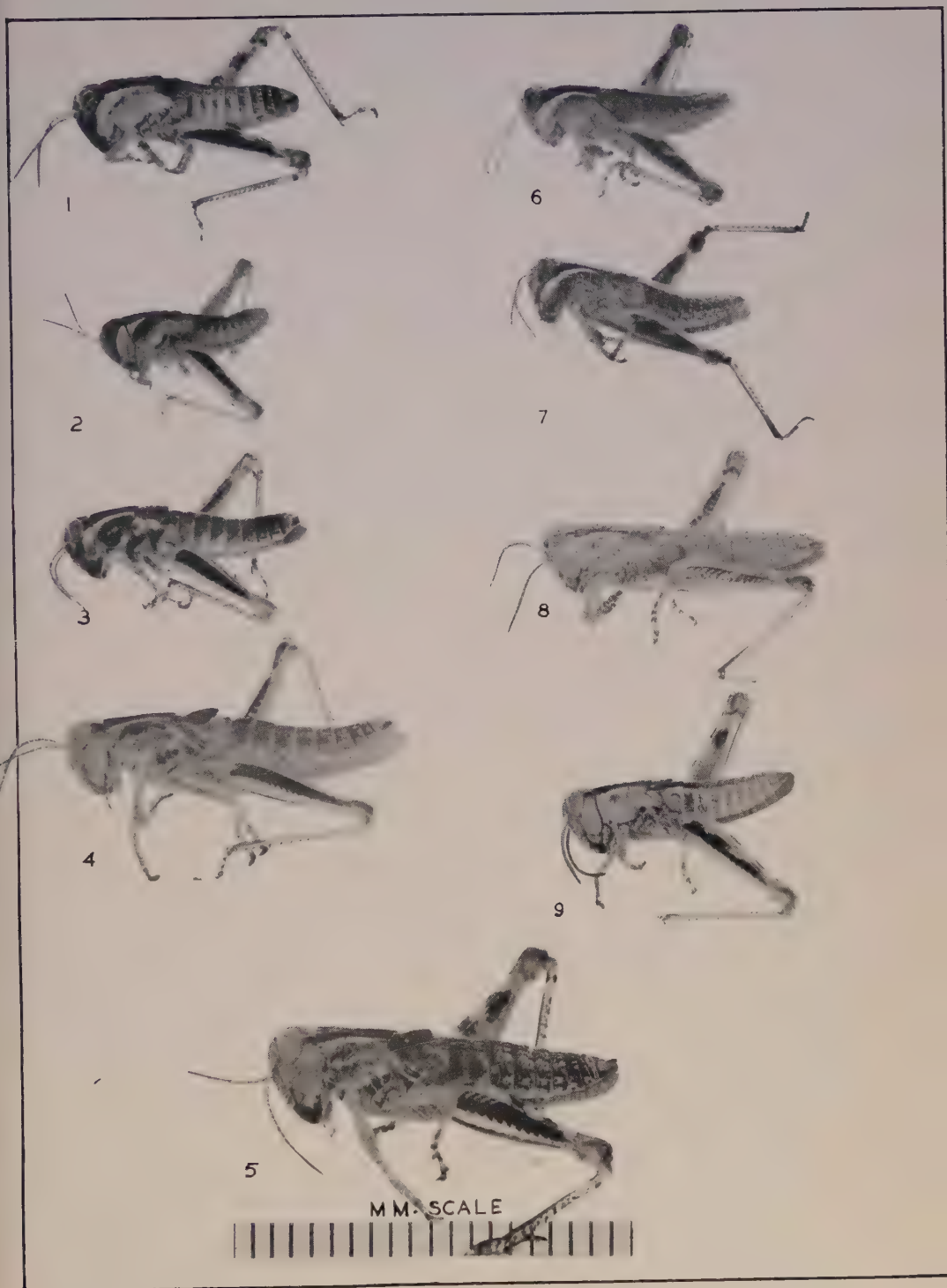
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PLATE VII. Fourth Instar Males (× 3) (Preserved material).

FIGURE 1. *M. huroni* Blatch.
FIGURE 2. *M. stonei* Rehn.
FIGURE 3. *M. angustipennis* (Dodge).
FIGURE 4. *M. foedus foedus* Scud.
FIGURE 5. *M. packardii* Scud.
FIGURE 6. *M. bruneri* Scud.
FIGURE 7. *M. confusus* Scud.
FIGURE 8. *M. fasciatus* (F. Walk.).
FIGURE 9. *M. infantilis* Scud.
FIGURE 10. *M. gladstoni* (Scud.).
FIGURE 11. *M. occidentalis occidentalis* (Thom.).
FIGURE 12. *M. mexicanus mexicanus* (Sauss.)

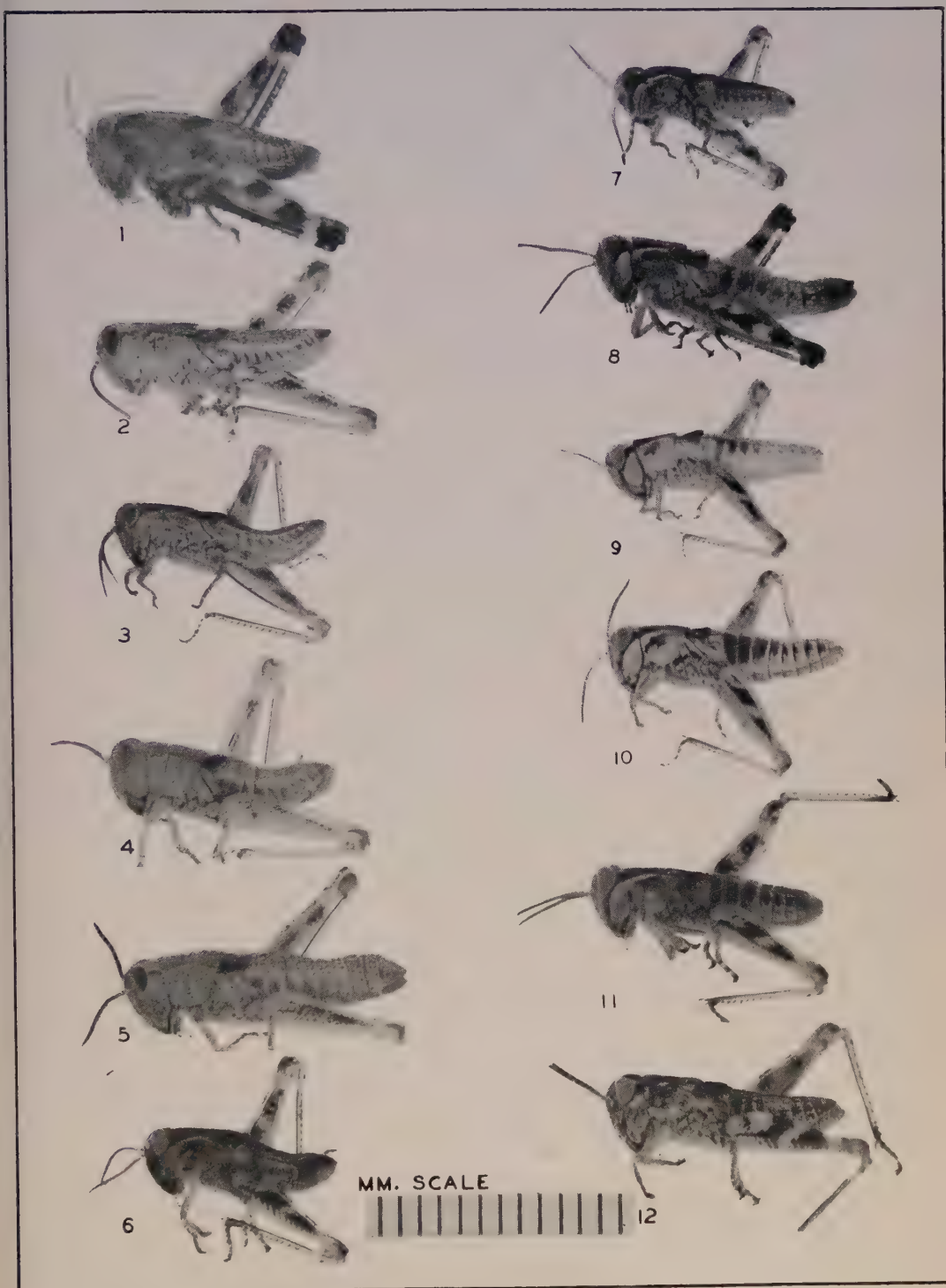
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PLATE VIII. Figures 1–21. Eyes of Third Instar Females (× 9). Figs. 22 and 23. Frontal Views (Preserved material).

FIGURE 1. *M. dawsoni* (Scud.).
FIGURE 2. *M. keeleri luridus* (Dodge).
FIGURE 3. *M. femur-rubrum femur-rubrum* (DeG.).
FIGURE 4. *M. bivittatus* (Say).
FIGURE 5. *M. differentialis* (Thom.).
FIGURE 6. *M. flavidus flavidus* Scud.
FIGURE 7. *M. bowditchi canus* Hebard.
FIGURE 8. *M. borealis junius* (Dodge).
FIGURE 9. *M. islandicus* Blatch.
FIGURE 10. *M. huroni* Blatch.
FIGURE 11. *M. stonei* Rehn.
FIGURE 12. *M. angustipennis* (Dodge).
FIGURE 13. *M. foedus foedus* Scud.
FIGURE 14. *M. packardii* Scud.
FIGURE 15. *M. confusus* Scud.
FIGURE 16. *M. fasciatus* (F. Walk.).
FIGURE 17. *M. infantilis* Scud.
FIGURE 18. *M. gladstoni* (Scud.).
FIGURE 19. *M. occidentalis occidentalis* (Thom.).
FIGURE 20. *M. mexicanus mexicanus* (Sauss.).
FIGURE 21. *M. bruneri* Scud.
FIGURE 22. *M. infantilis* Scud.
FIGURE 23. *M. gladstoni* (Scud.).

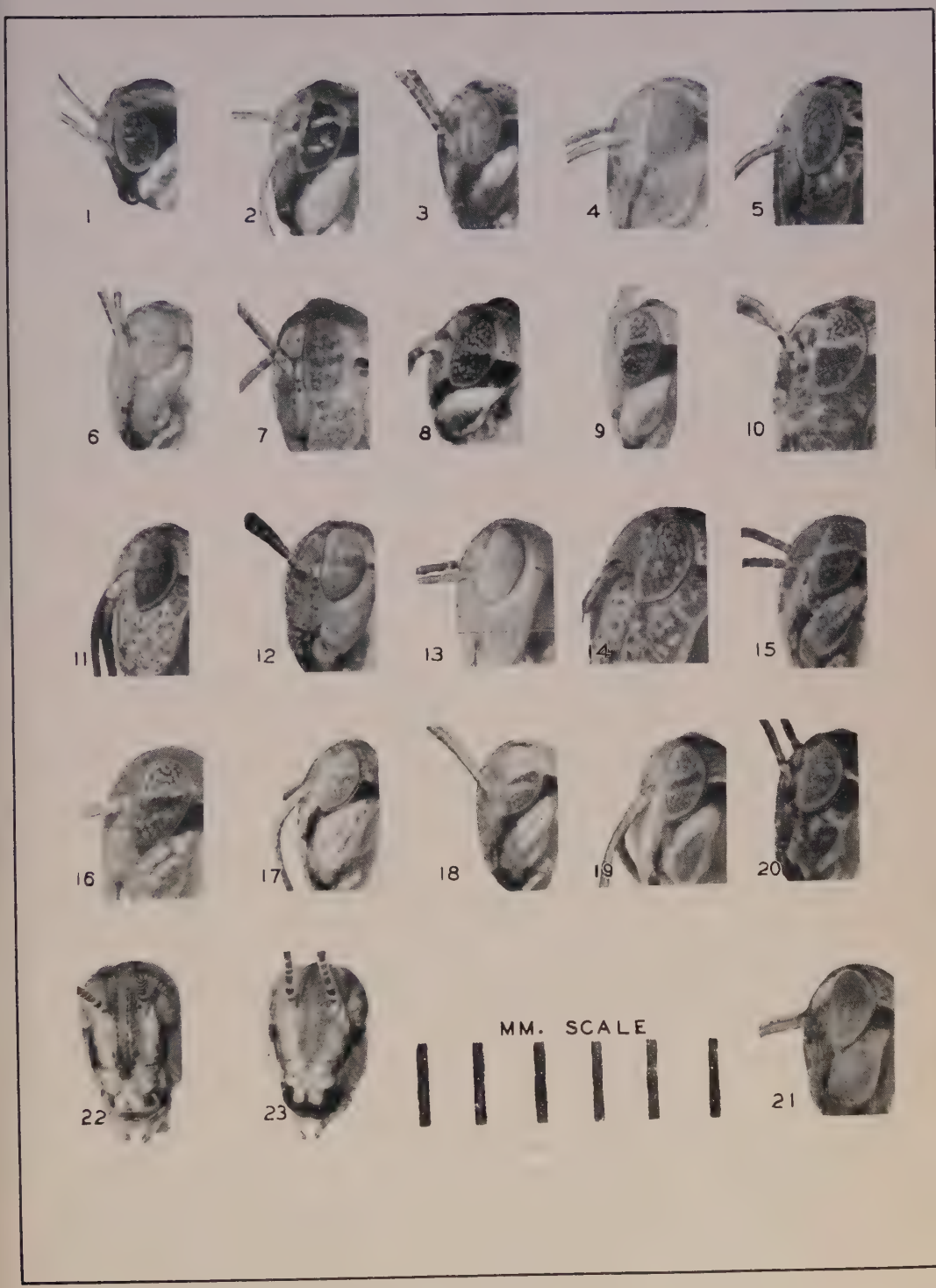
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PLATE IX. Fourth and Fifth Instar Male Genitalia (× 11).

FIGURE 1A. *M. dawsoni* (Scud.). Fourth lateral.
FIGURE 1B. *M. dawsoni* (Scud.). Fifth lateral.
FIGURE 1C. *M. dawsoni* (Scud.). Fifth dorsal.
FIGURE 1D. *M. dawsoni* (Scud.). Fourth dorsal.
FIGURE 2A. *M. fasciatus* (F. Walk.). Fourth lateral.
FIGURE 2B. *M. fasciatus* (F. Walk.). Fifth lateral.
FIGURE 2C. *M. fasciatus* (F. Walk.). Fifth dorsal.
FIGURE 2D. *M. fasciatus* (F. Walk.). Fourth dorsal.
FIGURE 3A. *M. mexicanus mexicanus* (Sauss.). Fourth lateral.
FIGURE 3B. *M. mexicanus mexicanus* (Sauss.). Fifth lateral.
FIGURE 3C. *M. mexicanus mexicanus* (Sauss.). Fifth dorsal.
FIGURE 3D. *M. mexicanus mexicanus* (Sauss.). Fourth dorsal.
FIGURE 4A. *M. flavidus flavidus* Scud. Fourth lateral.
FIGURE 4B. *M. flavidus flavidus* Scud. Fifth lateral.
FIGURE 4C. *M. flavidus flavidus* Scud. Fifth dorsal.
FIGURE 4D. *M. flavidus flavidus* Scud. Fourth dorsal.
FIGURE 5A. *M. bowditchi canus* Hebard. Fourth lateral.
FIGURE 5B. *M. bowditchi canus* Hebard. Fifth lateral.
FIGURE 5C. *M. bowditchi canus* Hebard. Fifth dorsal.
FIGURE 5D. *M. bowditchi canus* Hebard. Fourth dorsal.

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PLATE X. Fourth and Fifth Instar Male Genitalia (× 11).

FIGURE 6A. *M. femur-rubrum femur-rubrum* (DeG.). Fourth lateral.
FIGURE 6B. *M. femur-rubrum femur-rubrum* (DeG.). Fifth lateral.
FIGURE 6C. *M. femur-rubrum femur-rubrum* (DeG.). Fifth dorsal.
FIGURE 6D. *M. femur-rubrum femur-rubrum* (DeG.). Fourth dorsal.
FIGURE 7A. *M. borealis junius* (Dodge). Fourth lateral.
FIGURE 7B. *M. borealis ujnius* (Dodge). Fifth lateral.
FIGURE 7C. *M. borealis junius* (Dodge). Fifth dorsal.
FIGURE 7D. *M. borealis junius* (Dodge). Fourth dorsal.
FIGURE 8A. *M. angustipennis* (Dodge). Fourth lateral.
FIGURE 8B. *M. angustipennis* (Dodge). Fifth lateral.
FIGURE 8C. *M. angustipennis* (Dodge). Fifth dorsal.
FIGURE 8D. *M. angustipennis* (Dodge). Fourth dorsal.
FIGURE 9A. *M. foedus foedus* Scud. Fourth lateral.
FIGURE 9B. *M. foedus foedus* Scud. Fifth lateral.
FIGURE 9C. *M. foedus foedus* Scud. Fifth dorsal.
FIGURE 9D. *M. foedus foedus* Scud. Fourth dorsal.
FIGURE 10A. *M. packardii* Scud. Fourth lateral.
FIGURE 10B. *M. packardii* Scud. Fifth lateral.
FIGURE 10C. *M. packardii* Scud. Fifth dorsal.
FIGURE 10D. *M. packardii* Scud. Fourth dorsal.

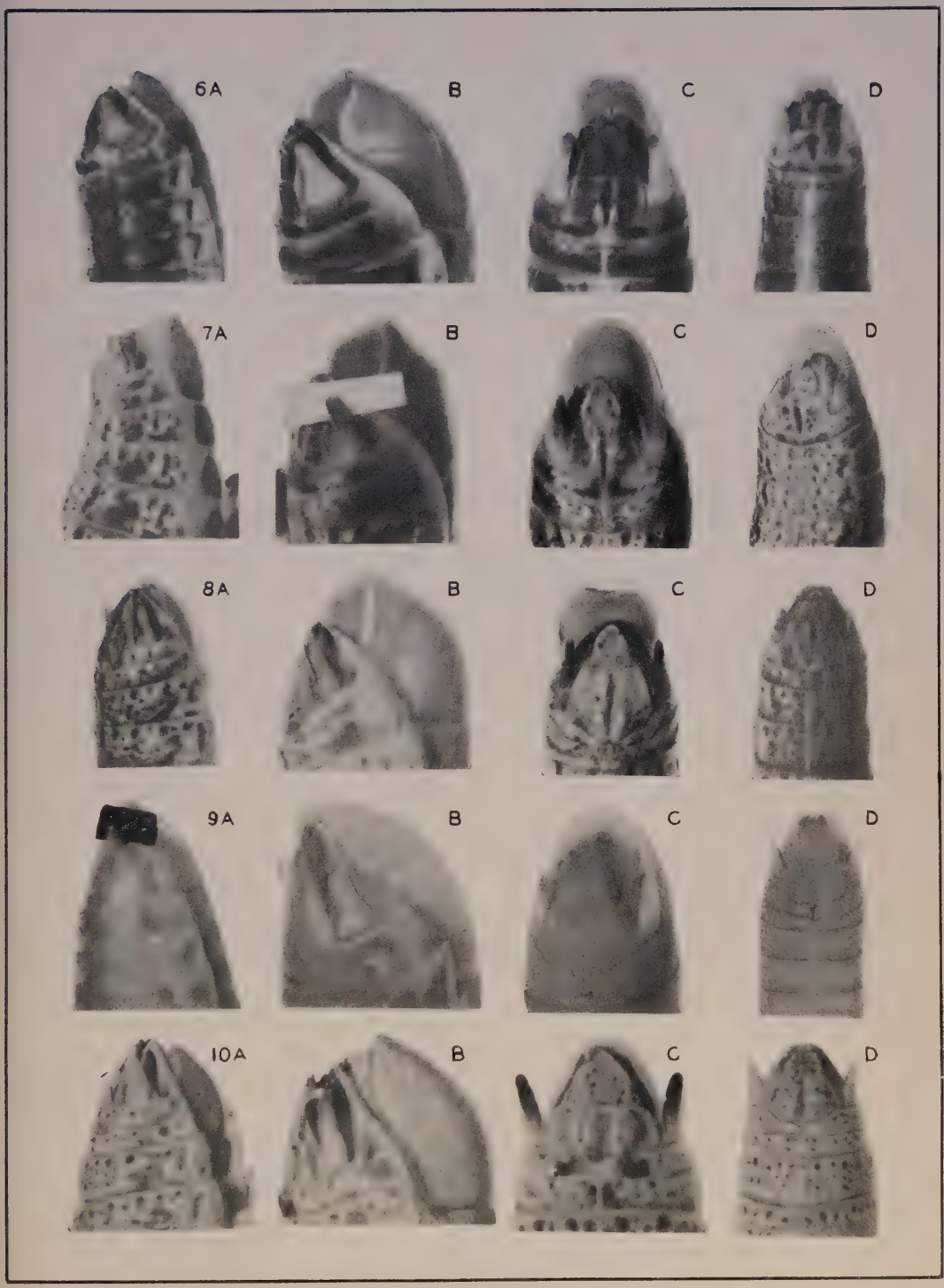
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PLATE XI. Fifth and fifth Instar Male Genitalia (× 11).

FIGURE 11A. *M. keeleri luridus* (Dodge). Fourth lateral.
FIGURE 11B. *M. keeleri luridus* (Dodge). Fifth lateral.
FIGURE 11C. *M. keeleri luridus* (Dodge). Fifth dorsal.
FIGURE 11D. *M. keeleri luridus* (Dodge). Fourth dorsal.
FIGURE 12A. *M. confusus* Scud. Fourth lateral.
FIGURE 12B. *M. confusus* Scud. Fifth lateral.
FIGURE 12C. *M. confusus* Scud. Fifth dorsal.
FIGURE 12D. *M. confusus* Scud. Fourth dorsal.
FIGURE 13A. *M. differentialis* (Thom.). Fourth lateral.
FIGURE 13B. *M. differentialis* (Thom.). Fifth lateral.
FIGURE 13C. *M. differentialis* (Thom.). Fifth dorsal.
FIGURE 13D. *M. differentialis* (Thom.). Fourth dorsal.
FIGURE 14A. *M. bivittatus* (Say). Fourth lateral
FIGURE 14B. *M. bivittatus* (Say). Fifth lateral.
FIGURE 14C. *M. bivittatus* (Say). Fifth dorsal.
FIGURE 14D. *M. bivittatus* (Say). Fourth dorsal.
FIGURE 15A. *M. infantilis* Scud. Fourth lateral.
FIGURE 15B. *M. infantilis* Scud. Fifth lateral.
FIGURE 15C. *M. infantilis* Scud. Fifth dorsal.
FIGURE 15D. *M. infantilis* Scud. Fourth dorsal.

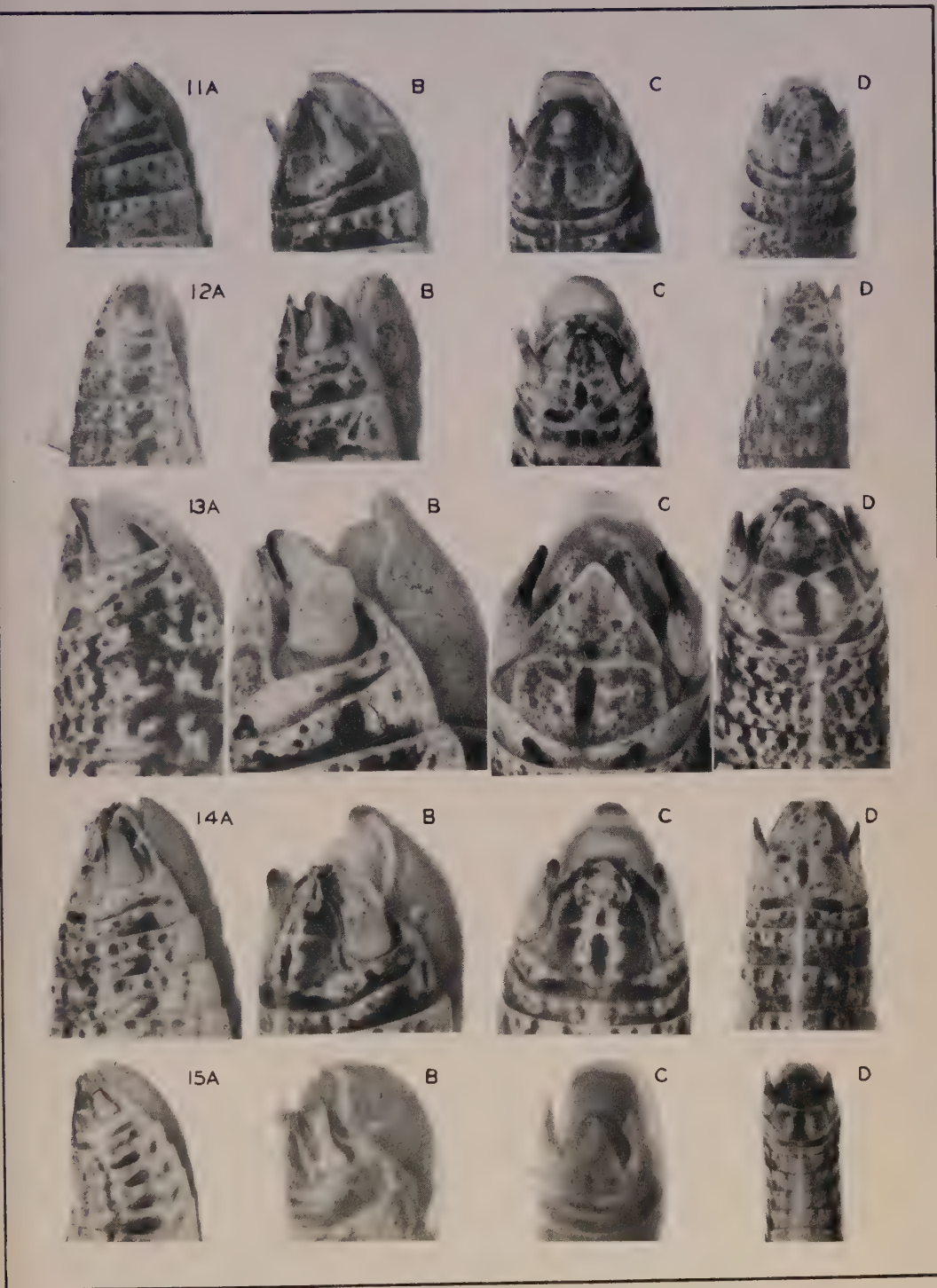
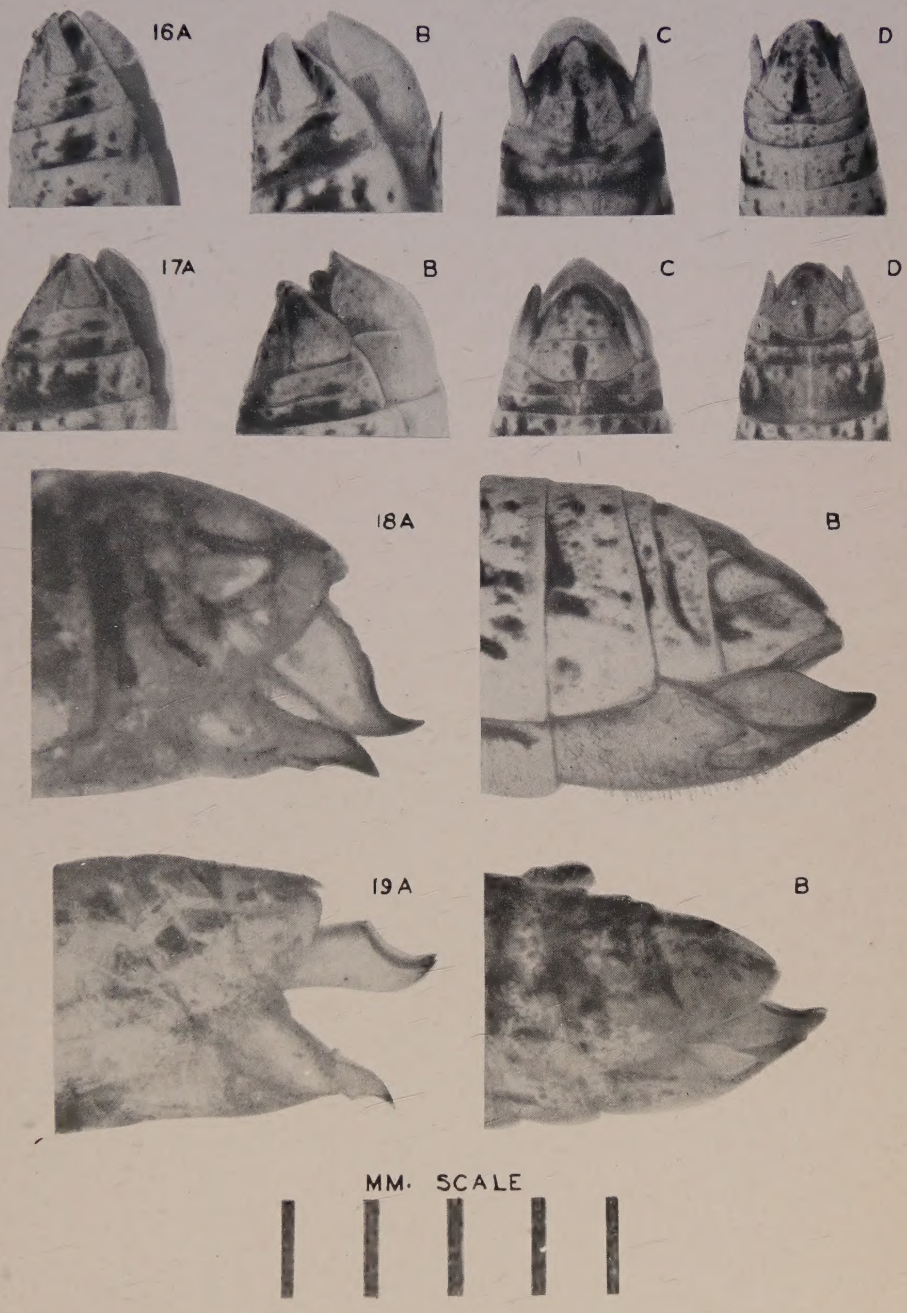

11A
B
C
D
12A
B
C
D
13A
B
C
D
14A
B
C
D
15A
B
C
D

PLATE XII. Male and Female Genitalia (× 11).

FIGURE 16A. *M. gladstoni* (Scud.). Fourth ♂ lateral.
FIGURE 16B. *M. gladstoni* (Scud.). Fifth ♂ lateral.
FIGURE 16C. *M. gladstoni* (Scud.). Fifth ♂ dorsal.
FIGURE 16D. *M. gladstoni* (Scud.). Fourth ♂ dorsal.
FIGURE 17A. *M. occidentalis occidentalis* (Thom.). Fourth ♂ lateral.
FIGURE 17B. *M. occidentalis occidentalis* (Thom.). Fifth ♂ lateral.
FIGURE 17C. *M. occidentalis occidentalis* (Thom.). Fifth ♂ dorsal.
FIGURE 17D. *M. occidentalis occidentalis* (Thom.). Fourth ♂ dorsal.
FIGURE 18A. *M. differentialis* (Thom.). Adult ♀ lateral.
FIGURE 18B. *M. differentialis* (Thom.). Fifth ♀ lateral.
FIGURE 19A. *M. angustipennis* (Dodge). Adult ♀ lateral.
FIGURE 19B. *M. angustipennis* (Dodge). Fifth ♀ lateral.


16A
B
C
D
17A
B
C
D
18A
B
19A
B
MM. SCALE

BOOK REVIEW

NEW CROPS FOR THE NEW WORLD. Edited by Charles Morrow Wilson. 295 pp., 32 plates. The Macmillan Company, New York. 1945. $4.50.

This volume discusses in popular form the introduction and development of new crops in America. Emphasis is placed almost entirely on crops that can be produced in South and Central America, or, in a few instances, on plants native to these areas, which may be grown in southern United States.

The term crops is not limited to plants and plant products but includes livestock and animal products, such as silk. With the exception of brief introductions by the Editor the text has been prepared by specialists in various fields.

Wilson Popenoe discusses tropical fruits and cinchona; Edgar Anderson, maize; Albert O. Rhoad, livestock breeds; Miriam L. Bomhard, palm oils and waxes; Walter N. Bangham, rubber; E. C. Higbee, drug and medicinal crops; C. P. Clausen, biological control of insect pests; Arthur Bevan, forest resources; George E. Adames, silk; Atherton Lee, bamboos; A. T. Erwin, peppers; B. Y. Morrison, flowers and the problems of plant introduction; P. Honig, cane sugar; and V. C. Dunlap, miscellaneous fibre and oil plants and timber trees.

As might be expected in a work of this kind where so many authors are involved the treatment of the subject matter tends to lack uniformity. From the standpoint of the popular reader some sections are exceedingly well done. For example, the story of silkworm culture in Brazil is told in an eminently readable narrative style which presents most of the significant data without becoming pedantic. Other sections do not appeal nearly so much to the average reader.

Work which has been done during the war on stimulating the production of rubber, cinchona, and various fibres in America is especially emphasized.

The volume is somewhat lacking in coherence and appears to have been rather hastily edited since one notes a considerable number of typographical errors. There are a number of excellent photographs illustrating the crops under discussion.

From the point of view of the agriculturalist of Canada or northern United States (which after all is part of the "New World") the volume contains relatively little of immediate concern. As a popular study of economic botany and the shifting of crops from one part of the world to another the compilation will be of interest to a wide range of readers.

HAROLD A. SENN.